# NAVAL POSTGRADUATE SCHOOL

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## MBA PROFESSIONAL REPORT

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**Best Value Analysis of Tool/Individual Material Readiness List (IMRL) Items for Carrier Air Wing Five (CVW-5) F/A-18 Hornet Squadrons from NAF Atsugi to MCAS Iwakuni, Japan**

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**By: Jose A. Martinez**
**Gavin D. Guidry**

**June 2012**

**Advisors: Geraldo Ferrer,**
**Keebom Kang**

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In 2005, a U.S.-Japan Security Consultative Committee agreed to shift the Carrier Air Wing Five (CVW-5) homeport from Atsugi Naval Air Station (NAS), Japan, to Marine Corps Air Station Iwakuni (MCASI), Japan, in 2016. Currently the 35 mile distance between Atsugi, where the air wing is based and Yokosuka, where the carrier is docked, does not constitute a significant burden to the supply chain. However, when CVW-5 F/A-18 Hornets are repositioned to MCAS Iwakuni, it will significantly impact transportation costs due to the additional 542-mile distance to move Tool/IMRL assets to the carrier for air wing embarkation. In the same timeframe of the air wing home port transition, the composition of the air wing will be evolving to become the Navy's first unit comprised of all Hornet variant aircraft. This analysis tries to determine the cost savings that may be involved with consolidation of Tool/IMRL outfitting allowances. Additionally, the analysis shows that MCAS Iwakuni may bring further asset exploitation opportunities due to the Marine Hornet squadrons already based there, whereas Atsugi has no Hornet presence other than CVW-5.


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Jose A. Martinez, Lieutenant Commander, United States Navy
Gavin D. Guidry, Lieutenant, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

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Authors: ________________________________________
Jose A. Martinez

________________________________________
Gavin D. Guidry

Approved by: ________________________________________
Dr. Geraldo Ferrer
Lead Advisor

________________________________________
Dr. Keebom Kang
Support Advisor

________________________________________
William R. Gates, Dean
Graduate School of Business and Public Policy

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## ABSTRACT

In 2005, a U.S.-Japan Security Consultative Committee agreed to shift the Carrier Air Wing Five (CVW-5) homeport from Atsugi Naval Air Station (NAS), Japan, to Marine Corps Air Station Iwakuni (MCASI), Japan, in 2016. Currently the 35 mile distance between Atsugi, where the air wing is based and Yokosuka, where the carrier is docked, does not constitute a significant burden to the supply chain. However, when CVW-5 F/A-18 Hornets are repositioned to MCAS Iwakuni, it will significantly impact transportation costs due to the additional 542-mile distance to move Tool/IMRL assets to the carrier for air wing embarkation. In the same timeframe of the air wing home port transition, the composition of the air wing will be evolving to become the Navy's first unit comprised of all Hornet variant aircraft. This analysis tries to determine the cost savings that may be involved with consolidation of Tool/IMRL outfitting allowances. Additionally, the analysis shows that MCAS Iwakuni may bring further asset exploitation opportunities due to the Marine Hornet squadrons already based there, whereas Atsugi has no Hornet presence other than CVW-5.

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# LIST OF ACRONYMS AND ABBREVIATIONS

Aircraft Controlling Custodians (ACC)

Aircraft Rescue and Firefighting (ARFF)

Aircraft Maintenance Material Readiness List (AMMRL)

Alliance Transformation and Realignment Oversight Panel (ATOP)

Aviation Maintenance Inspection (AMI)

Aviation Maintenance Management Team (AMMT)

Area of Responsibility (AOR)

Assistant Maintenance Officer (AMO)

Aviation Fleet Maintenance (AFM)

Calibrateable Items (METCAL)

Carrier Air Wing Five (CVW-5)

Chief of Naval Operation (CNO)

Commander, Fleet Activities Yokosuka, Japan (CFAY)

Commander Fleet Readiness Center (COMFRC)

Commander, Naval Air Forces (CNAF)

COMNAVAIRFOR (CNAF)

Commander, Naval Air Forces Pacific (CNAP)

Commander, Naval Installations Command (CNIC)

Commander, Naval Air Forces Instruction (COMNAVAIRFORINST)

Continuous Process Improvement (CPI)

Expeditionary Air Fields (EAF)

Field Landing Carrier Practice (FCLP)

Fleet Readiness Center (FRC)

Foreign Object Damage (FOD)

Forward Deployed Naval Forces (FDNF)

Ground Support Equipment (GSE)

IMRL Revision Request (IRR)

Indirect Hire Agreement (IHA)
Individual Material Readiness List (IMRL)
Inter-Deployment Readiness Cycle (IDRC)
Intermediate Maintenance Department (IMA)
Japan Maritime Self-Defense Force (JMSDF)
Japan Self-Defense Force (JSDF)
Local Asset Management System (LAMS)
Maintenance Material Control Officer (MMCO)
Maintenance Officer (MO)
Maintenance Program Assist (MPA)
Marine Aircraft Group 12 (MAG 12)
Marine All-Weather Fighter Attack Squadron 242 (VMFA-242)
Marine Aviation Logistics Squadron 12 (MALS 12)
Marine Corps Air Station Iwakuni (MCAS Iwakuni)
Marine Wing Support Group 17 (MWSG 17)
Marine Wing Support Squadron 171 (MWSS 171)
Master Labor Contract (MLC)
Mean Administrative Delay Time (MAdmDT)
Mean Down Time (MDT)
Mean Down Time for Documentation (MDTD)
Mean Down Time for Other Reasons (MDTOR)
Mean Down Time for Training (MDTT)
Mean Logistics Delay Time (MLDT)
Mean Supply Response Time (MSRT)
Mean Time Between Failures (MTBF)
Mean Time to Repair (MTTR)
National Stock Number (NSN)
Naval Air Facility (NAF)
Naval Air Station (NAS)
Naval Air Systems Command (NAVAIR)

Naval Aviation Enterprise (NAE)

Naval Aviation Maintenance Program (NAMP)

Office of Management and Budget (OMB)

Office of the Chief of Naval Operations Instruction (OPNAVINST)

Operation Tempo (OPTEMPO)

Operations and Maintenance/Navy (O&MN)

Organizational Level (O-Level)

Security Consultive Committee (SCC)

Strike Fighter Advanced Readiness Program (SFARP)

Subject-Matter Expert (SME)

Support Equipment Controlling Authority (SECA)

Support Equipment Resource Management Information System (SERMIS)

Support Equipment Planned Maintenance System (SEPMS)

Test Program Sets (TPS)

Tool Control Manual (TCM)

Tool Control Program (TCP)

Transportation, Inventory, Motion, Waiting, Over-Production, Over-Processing, and Defects (TIMWOOD)

Type Commander (TYCOM)

Type/Model/Series (TMS)

United States Marine Corps (USMC)

Weapons Replaceable Assemblies (WRA)

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# I. INTRODUCTION

## A. BACKGROUND

On October 29, 2005, the U.S.–Japan Security Consultative Committee (SCC) reached an understanding on common goals and objectives and agreed to shift the homeport for Carrier Air Wing Five (CVW-5) from Naval Air Facility (NAF) Atsugi, Japan, to Marine Corps Air Station Iwakuni (MCAS Iwakuni), Japan, in 2016 (Rice, Rumsfeld, Machimura, & Ohno, 2005). This relocation will increase shipping costs of tools and individual material readiness list (IMRL) items with each associated deployment from the current 25 miles (the distance from NAF Atsugi) to approximately 537 miles (the distance from MCAS Iwakuni to Commander Fleet Activities Yokosuka [CFAY]). In this project, we assume the typical CVW-5 deployment schedule.

One of the principal reasons why CVW-5 fixed-wing assets are relocating to MCAS Iwakuni is due to the noise they make when conducting nighttime field landing carrier practice (FCLP) at NAF Atsugi. Constant noise from this activity has been a concern of residents of Ayase, Yamato, and nearby communities for many years. In an effort to ease some of the concerns and noise levels, the U.S. Navy and the government of Japan agreed to move nighttime landing practices to another location, with Iwo Jima heading the list as the leading candidate.

There are three cities near NAF Atsugi that required immediate attention due to their increasing populations. The city of Atsugi had a population of 208,627 in October 1995 and that increased to 224,420 in October 2010 (Brinkhoff, 2011a). Figure 1 shows the population growth of Atsugi from 1995 to 2010.

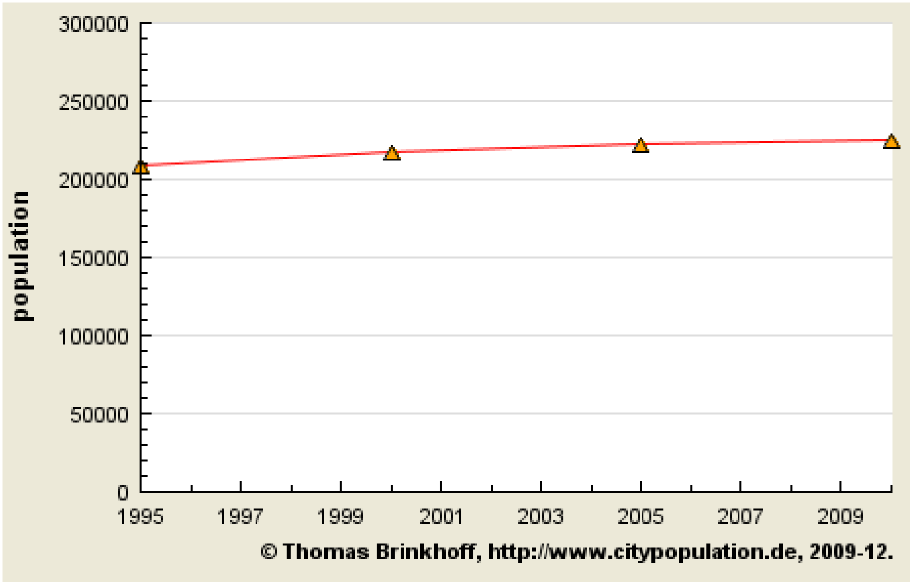


**Figure 1. Population Growth Chart of Atsugi**

(From Brinkhoff, 2011*a*)

The city of Ebina had a population of 113,430 in October 1995, which increased to 127,707 in October 2010 (Brinkhoff, 2011c). Figure 2 shows the population growth of Ebina from 1995 to 2010.

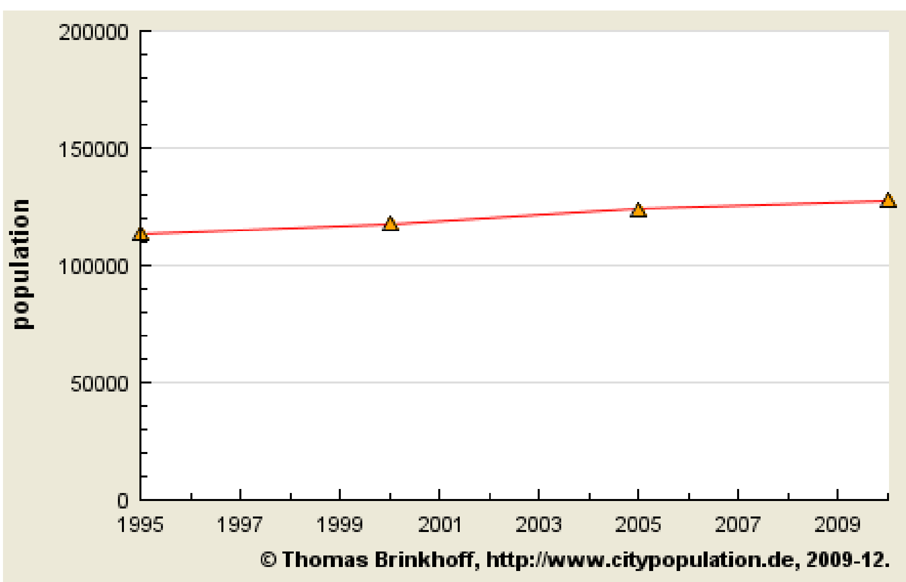


**Figure 2. Population Growth Chart of Ebina**

(From Brinkhoff, 2011*c*)

The city of Ayase had a population of 110,680 in October 1995, which increased to 129,167 in October 2010 (Brinkhoff, 2011b). Figure 3 shows the population growth of Ayase from 1995 to 2010.

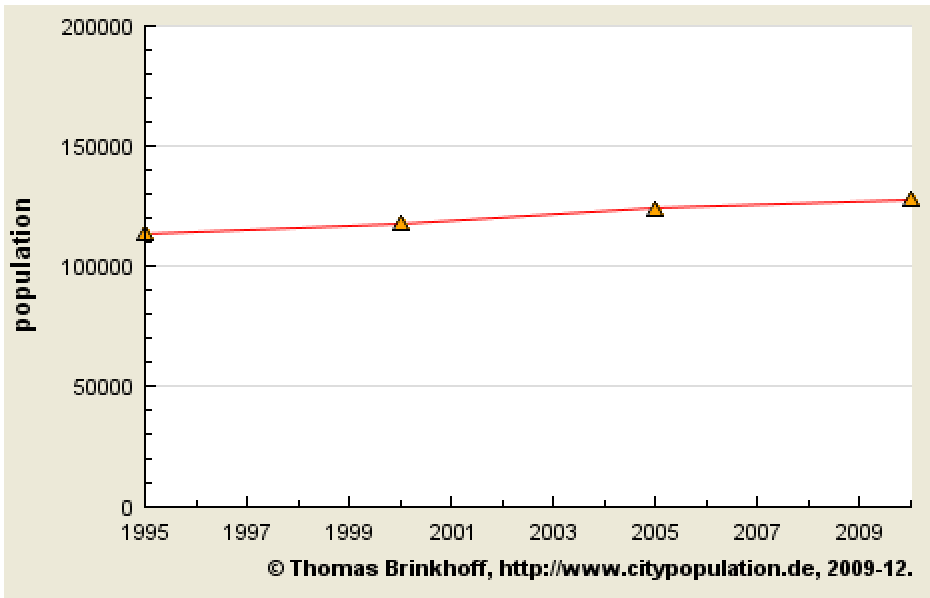


**Figure 3. Population Growth Chart of Ayase**
(From Brinkhoff, 2011*b*)

The objective of this project is to further leverage a prior thesis project titled *Best Value Analysis of Movement Strategies for Carrier Air Wing Five (CVW-5) from Iwakuni to Yokosuka, Japan* (Debord, Coleman, & Hodge, 2011). We use some of their findings for transportation and shipping costs to determine whether there is a cost savings to the Naval Aviation Enterprise (NAE) of dual-sited equipage and, if so, whether there is an optimal mix of tools (IMRL) that can be spread among the fixed-wing assets of CVW-5.

### 1. Current Operational Picture

The following major commands are institutional stakeholders in the topic of this thesis and are relevant in any decisions that the thesis data present.

### *a. United States Navy 7th Fleet*

The United States Navy's 7th Fleet was established on March 15, 1943, and today it is the largest forward deployed U.S. fleet in the world. It has an area of responsibility that includes the Western Pacific and Indian Oceans. Commander, U.S. 7th Fleet participated in several Pacific campaigns, including the Battle of Leyte Gulf in the Philippines during World War II as the naval combatant commander under Supreme Commander Southwest Pacific Area, General Douglas MacArthur. A few years later, on February 11, 1950, the force assumed the name that it holds today—United States Navy 7th Fleet (Commander, United States Navy 7th Fleet, 2012b). Figure 4 shows the key elements of the United States Navy 7th Fleet.


**Figure 4. United States Navy 7th Fleet Elements**

(From Federation of American Scientists, 1999)

The United States Navy's 7th Fleet units have participated in every major military operation since being established in 1950. During the Korean War, the first Navy jet aircraft used in combat was launched from a Task Force 77 carrier on July 3, 1950, and the famous landings in Inchon, Korea, were conducted by the United States Navy 7th Fleet amphibious ships. The battleships USS *Iowa (BB 61)*, USS *New Jersey (BB 62)*,

USS *Missouri (BB 63)*, and USS *Wisconsin (BB 64)* all served as flagships for Commander, United States Navy 7th Fleet during the Korean War. This fleet has participated in all combat operations, including Vietnam and the Global War on Terrorism (Commander, United States Navy 7th Fleet, 2012b).

Within hours of the March 11, 2011, devastating earthquake and tsunami that struck northern Japan, the United States Navy 7th Fleet mobilized 22 ships, 132 aircraft, and more than 15,000 personnel to support the Japan Self-Defense Forces (JSDF) in the largest recovery effort in their history. The relief operation that followed was named Operation Tomodachi, after the Japanese word for "friend" (Commander, United States Navy 7th Fleet, 2012b). This operation demonstrated the quick responsiveness and flexibility of the United States Navy 7th Fleet and showed the strong bonds that tie relations between the U.S. and Japan.

#### *b. NAF Atsugi*

NAF Atsugi is the only naval installation supporting an entire air wing and is located 25 miles northwest of CFAY. It has been home to U.S. Navy personnel and their families for over 50 years. The base consists of approximately 1,249 acres and lies in the Kanto Plain region on Honshu, the main island of Japan. NAF Atsugi's strategic importance has been key to CVW-5's success by providing state-of-the-art facilities, maintenance, and logistics services to support the "Tip of the Sword" in the Western Pacific (Commander, Navy Installations Command [CNIC], 2012b). Figure 5 shows a relational map of NAF Atsugi.

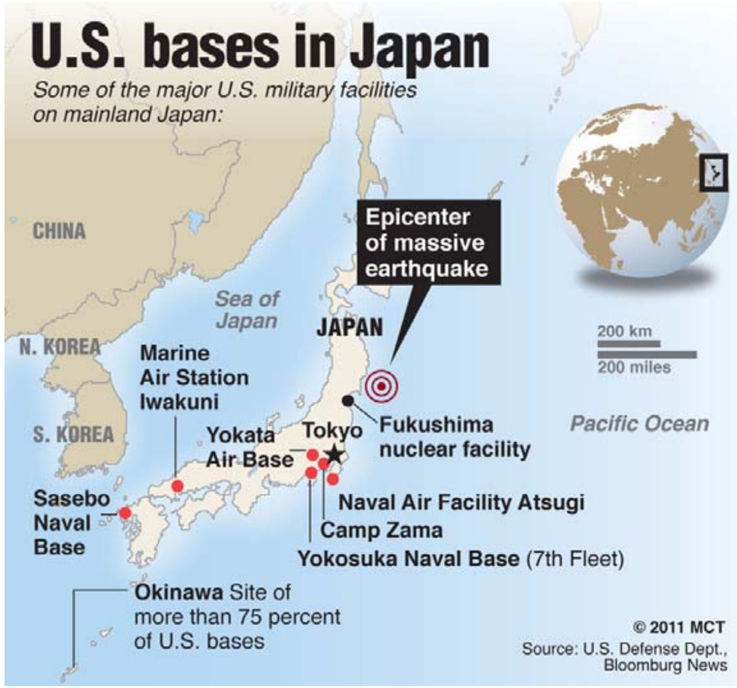


**Figure 5. Relational Map of NAF Atsugi**

(From Ruskin & Strobel, 2011)

#### *c. Fleet Activities Yokosuka*

CFAY is a 560-acre forward deployed naval base located near Yokohama. It is the Navy's largest, most strategically important overseas installation; CFAY has 82 tenant commands assigned to support operating forces in the Western Pacific, from Hawaii to the Persian Gulf. The base's primary mission is to support the 11 high operational tempo warships forward deployed to Yokosuka and the United States Navy 7th Fleet flagship, USS *Blue Ridge* (LCC 19; CNIC, 2012a). Figure 6 shows an aerial map of CFAY.

**Figure 6. Aerial Map of Commander, Fleet Activities Yokosuka**
(From Powers, 2012)

#### *d. USS George Washington (CVN 73): Forward Deployed Carrier*

In September 2008, USS *George Washington* (CVN 73) replaced USS *Kitty Hawk* (CV 63) at a cross-decking ceremony in San Diego, making her the only forward deployed carrier in the Pacific (CNIC, 2012b). Figure 7 shows the USS *George Washington* arriving to her new home port of CFAY.


**Figure 7. USS *George Washington* (CVN 73) Arriving New Homeport CFAY**
(From Davis, 2008)

#### *e. Carrier Air Wing Five*

CVW-5 has proudly earned the nickname as the nation's only "911" air wing. It is a combat strike element of the United States Navy's 7th Fleet and is the nation's only forward deployed carrier strike group. CVW-5 consists of Strike Fighter Squadron 27, Strike Fighter Squadron 115, and Strike Fighter Squadron 195, each flying F/A-18E Super Hornets; Strike Fighter Squadron 102, flying the F/A-18F Super Hornet; Electronic Attack Squadron 141, which will be flying the E/A-18G (Growler) in the near future; Carrier Airborne Early Warning Squadron 115, flying the Hawkeye 2000; Fleet Logistics Support Squadron 30 Detachment 5, flying the C-2 Greyhound; and Helicopter Antisubmarine Squadron 14, flying the HH-60F/H Seahawk (CNIC, 2012b). CVW-5 has

been stationed at NAF Atsugi for over 28 years and is the only permanently forward deployed carrier air wing in the U.S. Navy. Figure 8 shows CVW-5 fixed-wing assets flying over Mt. Fuji.

**Figure 8. CVW-5 Aircraft Flying Over Mt. Fuji**
(From Airliners, 2011)

#### *f. Marine Corps Air Station Iwakuni*

MCAS Iwakuni, Japan, is located approximately 600 miles southwest of Tokyo. The base is home to almost half of the 1st Marine Aircraft Wing that is headquartered on Okinawa, elements of the 3rd Force Service Support Group, Fleet Air Wing 31 of the Japan Maritime Self-Defense Force (JMSDF), and other units of JMSDF. The base is home to numerous F/A-18C/Ds. It presently has approximately 15,000 personnel, including Japanese national employees in five major tenants (U.S. Marine Corps [USMC], 2012a). Figure 9 shows an overhead view of MCAS Iwakuni.

**Figure 9. Overhead View of MCAS Iwakuni**

(From Military Bases, 2012)

(1) The Mission of Marine All-Weather Fighter Attack Squadron 242 (VMFA-242) is “to support the MAGTF commander by providing supporting arms coordination, conducting reconnaissance, and destroying surface targets and enemy aircraft day or night under all weather conditions during expeditionary, joint, or combined operations” (USMC, 2012b).

(2) The Mission of Marine Aircraft Group 12 (MAG 12) is “to conduct anti-air warfare and offensive air support operations in support of Fleet Marine Forces from advanced base, expeditionary airfields or aircraft carriers and conduct such air operations as may be directed” (USMC, 2012b).

(3) The Mission of Marine Aviation Logistics Squadron 12 (MALS 12) is “to provide aviation logistics expertise, planning and material to MAG-

12 and its subordinate tactical aircraft squadrons in order to support operational contingencies, theater security cooperation plans, and training exercises in the Pacific Command area of responsibility" (USMC, 2012b).

(4) The Mission of Marine Wing Support Squadron 171 (MWSS 171) is to provide all essential Aviation Ground Support requirements to a designated fixed-wing component of an aviation combat element and all supporting or attached elements of the Marine Air Control Group. Additionally, the squadron has the implied mission to supplement airbase facilities and services at MCAS Iwakuni. Forming an essential element of Marine Wing Support Group 17 and 1st Marine Aircraft Wing, Marine Wing Support Squadron 171 routinely fulfills its demanding responsibilities in Iwakuni and also in deployed locations around the Pacific Rim (USMC, 2012b).

The Marine Corps Aviation Ground Support performs the following 14 functions (USMC, 2012b):

1. internal airfield communications;
2. weather services;
3. expeditionary air fields (EAF) services;
4. aircraft rescue and firefighting (ARFF);
5. aircraft and ground refueling;
6. explosive ordnance disposal;
7. essential engineer services;
8. motor transport;
9. field mess facilities;
10. sick-call and aviation medical functions;
11. individual/unit training of organic and selected personnel;
12. nuclear, biological, and chemical defense;
13. security and law enforcement services; and
14. air base commandant functions.

(5) The mission of Marine Wing Support Group 17 (MWSG 17) is "to provide essential ground support requirements (less aircraft supply, maintenance,

and ordnance) to a designated MAW. The MWSG is organized and equipped for employment as an integral unit in **support** of the MAW" (USMC, 2012b).

#### g. *Maintenance Labor*

Japanese workers on U.S. military bases in Japan are hired under bilateral labor contracts, the master labor contract (MLC) and the indirect hire agreement (IHA). MLC positions are open only to permanent residents of Japan who are not U.S. civilian employees for the military, Service members, or their family members. IHA positions are available to permanent residents of Japan who are not U.S. citizens. The unique nature of the labor agreements has caused friction, at times, between Japanese employees and U.S. supervisors. There are approximately 8,900 MLC and IHA employees working on 23 military facilities, according to the Labor Management Office, the Japanese government's labor administration office for MLC and IHA workers for U.S. Forces Japan (Sumida, 2004).

### 2. Pending Operational Picture

As a direct result of the U. S.–Japan SCC document of October 29, 2005 (Rice et al., 2005), the Navy will relocate approximately 64 CVW-5 fixed-wing assets from NAF Atsugi to MCAS Iwakuni in 2016. Figure 10 shows a relational map between the current situation in Atsugi and the future location for CVW-5 fixed-wing aircraft. The move will not affect the helicopter squadrons because they will remain at NAF Atsugi. Figure 10 shows a relational map of U.S. military bases in Japan.

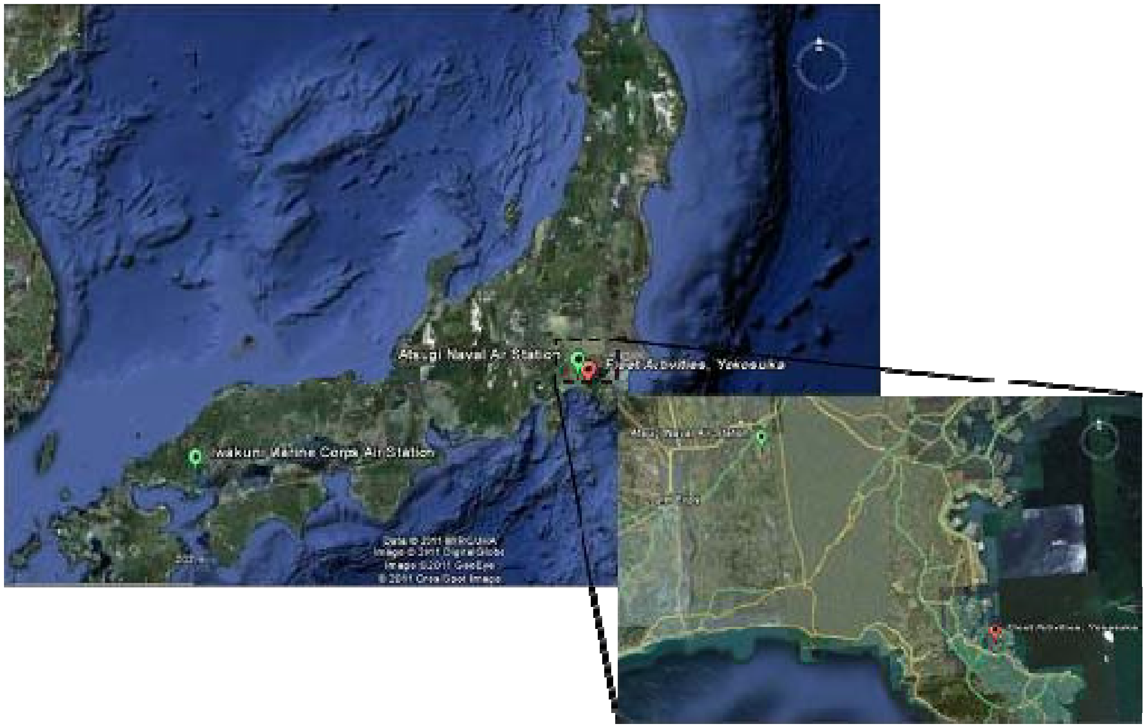


**Figure 10. Relational Map of U.S. Military Bases in Japan**
(From Debord, Coleman, & Hodge, 2011)

When CVW-5 relocates in 2016 to MCAS Iwakuni, the standard operating procedure for them would be to take their entire tools/IMRL equipage with them. In this project, we examine the current tools/IMRL transportation process, CVW-5 transportation options, along with CVW-5 transportation options, and the redundancies and costs associated with these options. This analysis may be used as a decision and evaluation tool to support the procurement, distribution, and accountability policy for CVW-5's fixed-wing tools/IMRL.

#### 3. About This Thesis

In this project, we analyze Tools/IMRL requirements for CVW-5 fixed-wing assets, and we determine whether there is a more beneficial quantity and distribution of these assets throughout the dual sites of CFAY–MCAS Iwakuni. In Chapter II, we outline our assumptions and data-collection techniques.

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# II. TOOL/INDIVIDUAL MATERIAL READINESS LIST PRACTICES

The function of the second chapter is to provide an understanding of the classes of material utilized in the maintenance and material support of an air wing and the level of oversight provided for the oversight of these materials. The limitations that governing references and responsible entities impose must be understood and addressed prior to making any changes to outfitting quantities and procedures as they exist under the current paradigm.

## A. INDIVIDUAL MATERIAL READINESS LIST

IMRL items are a subset of the class of items known as aircraft maintenance material readiness list (AMMRL) items (Commander, Naval Air Forces [CNAF], 2009). AMMRL items encompass a wide range of assets used at all levels of aviation maintenance, from large ground-support equipment (GSE) items, such as hydraulic generators, to intricate test program sets (TPS) used in the repair of complex electronic weapons replaceable assemblies (WRA). The primary objective of the AMMRL program is to provide operational IMRL support equipment to satisfy flight and personal safety requirements in direct support of mission effectiveness (CNAF, 2008). Across the fleet, there are approximately 37,000 discrete line items of AMMRL assets that are managed and used in aircraft maintenance evolutions at all levels (CNAF, 2009). Many IMRL assets are very specialized to a particular application and, therefore, have a scarcity and high cost associated with their procurement. For this reason, the Navy maintains databases at two levels to track these assets, as well as implements stringent requirements directing inventory managers to maintain strict control of their assigned catalog of items.

### 1. Governing References

The primary reference governing the management of AMMRL, and by extension IMRL, assets is the Naval Aviation Maintenance Program (NAMP) COMNAVAIRFORINST 4790.2A CH-2 (CNAF, 2009). In the third chapter of this report, we cover maintenance concepts, programs and processes, maintenance unit

departments, division organization, manpower management, and aviation officers; the applicable section is the area on programs and processes. The NAMP functions as a high-level guidance document for the programs it covers, and the details of individual programs are governed by specific references indicated by the NAMP for adherence to applicable standard operating procedures. In the case of AMMRL, the NAMP refers readers to the NAVAIRINST 13650.1 series for allowance and inventory control procedures, to the NAVAIRINST 13680.1 series for rework procedures, and to the NAVAIR 17-35MTL-1 series for calibration requirements of AMMRL assets (CNAF, 2009).

### 2. Coding of Assets

IMRL assets are assigned single-digit alphabetic codes to designate the type of item covered and to provide additional information on the type of transaction required for requisitioning the item (CNAF, 2008). The codes themselves are tied to supply and financial records for accountability purposes. The type of IMRL assets that are assigned reporting codes are the ones that are allocated to intermediate maintenance activities (IMA) and Fleet Readiness Centers (FRCs) for sub-custody to other activities (CNAF, 2009). The primary custody codes used are the following:

#### *a. Code P*

Large items, in excess of 200 pounds for immobilized equipment or 300 pounds for wheeled equipment, which exceed certain storage size authorizations. This category of IMRL also includes assets that are too fragile or likely to have their calibration coverage voided through misalignment during movement, limiting their transportability. Assets of this category are checked out to hosted commands by the applicable IMA when required for local operation (CNAF, 2008).

#### *b. Code D*

Items in a detachment list that have a code of D or E. The D code allows items assigned to a specific detachment to be grouped together for management, but this code is still subject to the same requirements of a P-coded item (CNAF, 2008).

#### *c. Code E*

Infrequently used items that are utilized on an average periodicity of less than once per month. These items are provided to the cognizant IMA and checked-out only to hosted activities for immediate use (CNAF, 2008).

#### *d. Code M*

Generic IMRL items that are not calibrateable and that are not covered by any other custody code. These units are issued and used in conjunction with calibrateable items (CNAF, 2008).

#### *e. Code N*

IMRL items that do not require calibration and are not covered by any other custody code (CNAF, 2008).

#### *f. Code L*

Items that do require calibration and management and are sub-custodied to organizational activities for use both while deployed and in homeport which are not covered by any other custody code (CNAF, 2008).

### 3. Responsible Levels

The list that follows describes the primary levels associated with IMRL program management and compliance. We highlight the principal responsibilities of these parties in this thesis, but a full listing of responsibilities can be found in the NAMP and the NAVAIRINST 13650.1 series publication.

#### *a. Aviation Support Equipment Program Manager*

The activity designated as the overall aviation SE program manager is COMNAVAIRSYSCOM (PMA-260). PMA-260 holds responsibilities at all levels of the support equipment life cycle, from initial design through development and testing, and into operational use. PMA-260's responsibility concludes only with asset disposition upon retirement. PMA-260 is also responsible for the funding of initial IMRL procurement of all covered activities. As part of the PMA-260 management of the operational life of a

support equipment asset, this activity also governs the technical documentation and training necessary to field the equipment and keep it in a useful status (CNAF, 2009).

#### *b. Support Equipment Controlling Authority*

The support equipment controlling authority (SECA) maintains an accurate accounting in the support equipment resource management information system (SERMIS) for all equipment in the custody of its responsible commands. By extension, the SECA is responsible for determining the authorized allowance of IMRL for weapons systems operated in its area of responsibility; the SECA must first approve any transfers of equipment or requests for asset augmentation prior to execution. Compliance with AMMRL procedures is accomplished thorough training provided to area commanders and a monthly transaction report verification conducted with reporting activities (CNAF, 2008).

#### *c. Area Commander*

The area commander is the appointed representative for the SECA within a specific geographic area of responsibility. The Area Commander ensures that subordinate activities remain in compliance with standard AMMRL procedures by making certain that only knowledgeable and qualified personnel are assigned to positions of authority in program management. A large component of this compliance is the maintenance of accurate Local Asset Management System (LAMS) files within the organizations as well as quarterly generated back-up records. Another, and also important, compliance requirement by the Area Commander is to ensure the accurate processing of the mandatory wall-to-wall IMRL inventories at the appropriate level and within prescribed periodicities (CNAF, 2008).

#### *d. Activity Level*

Physical compliance with AMMRL program requirements is accomplished at this level through interaction between the maintenance officer, respective division officers, work center supervisors, material control, and the assigned IMRL asset manager. At the top of the activity hierarchy, the maintenance officer (MO) must appoint an IMRL asset manager at least 30 days prior to the departure of the previous IMRL manager. The

assigned manager must be an E-5 or above and hold the IMRL management Naval Enlistment Code 9590. The requirement for the overlap is to enable the prospective manager to become familiar with the IMRL condition within the command prior to the departure of the previous subject-matter expert. The maintenance officer must also sign as the responsible officer on all surveys (DD Form 200) that are submitted for IMRL discrepancies (CNAF, 2008).

Division officers administratively maintain all IMRL for their assigned divisions and report compliance status to the maintenance officer for the completion of program requirements. The principal agents of the division officer in program compliance are the individual work center supervisors. The division officer reviews IMRL documents prior to up-line submission (CNAF, 2008).

The work center supervisors are the frontline IMRL managers who maintain an accurate listing of all assigned assets. They are charged with conducting the physical inventories and initiating the surveys for any discrepancies with assigned gear (CNAF, 2008).

The material control work center supervisor is responsible for ensuring the activity's compliance with AMMRL procedures and reporting its conformance to the maintenance officer. The IMRL asset manager is the agent who spearheads compliance activities. In addition to verifying the compliance of other activity levels with program requirements, the asset manager also performs administrative tasks to keep the activity on track, such as maintaining a 100% local asset management system (LAMS)-to-support equipment resource management information system (SERMIS) accuracy and submitting IMRL disposition requests as necessary. Due to their superior knowledge of the program, asset managers provide program training to all activity personnel (CNAF, 2008).

#### 4. Outfitting

Outfitting entails the procedures in place to achieve the equipage of valid IMRL requirements for operational activities. The mechanics of outfitting are described in the following list:

#### *a. Methods*

(1) Push—Assets purchased through NAVAIR-appropriate funds with no charge to the recipient activity. The support equipment controlling authority (SECA) and NAVAIR determine how assets should be allocated according to need, and site activation teams or the actual manufacturer of the equipment deliver the resources (CNAF, 2008).

(2) Pull—Performed with IMRL funding provided to an activity to ensure adequate material exists to cover maintenance activities and to facilitate the support of hosted activities (CNAF, 2008).

(3) Redistribution—The transfer of excess materials from one existing activity to another and the repurposing of material from eliminated activities (CNAF, 2008).

(4) Local manufacture—Assets that are not procured in their final form from a commercial source but are manufactured at the local level using technical data from the Naval Air Technical Data and Engineering Services Command (CNAF, 2008).

#### *b. Occasion*

(1) Initial outfitting—The function of providing IMRL assets to newly established activities under the coverage of an SECA. The SECA determines the asset requirements of the prospective activity approximately one year prior to its implementation and provisions the activity through either push or redistribution channels (CNAF, 2008).

(2) Re-outfitting—This process results from changes in the scope of an SECA-supported activity in which new requirements or operating environment changes nullify the previously existing IMRL authorization for the activity. Approximately one year prior to the change, the SECA will assess requirements driven by the changes in the supported activity's position and outfit the activity to the proper level through push, pull, and redistribution (CNAF, 2008).

### 5. Tracking Databases

The Navy uses two databases to track and allocate AMMRL based on the needs of fleet end users. The SERMIS is the higher level database SECAS use that contains information that subordinate activities provide up line (CNAF, 2009). The LAMS database is operated and maintained by local element commands as a method of updating the SERMIS and ensuring that a full picture of material availability is provided fleet wide (CNAF, 2008). The key source data that links the two databases is the Support Equipment Transaction Report (OPNAV 4790/64; CNAF, 2009). The existence of this form's fields in both databases enables one to feed the other. Further explanation of each program is provided in the following list.

#### *a. Support Equipment Resource Management Information System*

The SERMIS is a program fielded by COMNAVAIRSYSCOM PMA 260EA to identify and catalog the technical items used by all organizational, intermediate, and depot-level maintenance activities to perform repairs and upkeep on Navy aviation assets. The purpose of the data contained in the system is to provide SECAs with inventory control oversight into source, allowance, and inventory data from an electronic perspective (CNAF, 2009). In addition to the asset-tracking features of LAMS, the broader-scope architecture of the SERMIS facilitates redistribution of assets across activities, enables the scheduling of rework for listed assets, and makes configuration management of resources possible across varying platforms.

#### *b. Local Asset Management System*

The LAMS is also a computer-based program fielded by COMNAVAIRSYSCOM, but its purpose is the management of assets at the local command level, rather than on a fleet-wide basis. To standardize input to the SERMIS from the numerous individual AMMRL controlling commands, the LAMS is the only program authorized for use at the local level, and all support equipment transactions must be processed in this system. Prompt transaction report updates within this system ensure inventory accuracy across the aviation enterprise (CNAF, 2009).

### 6. Transfer Procedure

The transfer of IMRL from the permanent custody of one activity to another can be performed only under the direction of the SECA. Transfer authority is requested from the SECA through the completion of a formal IMRL revision request (IRR) on the part of the activity appealing for a tailoring of their asset allowance in an amount either upward or downward of what they are currently allotted. The processing of the IRR, as with all AMMRL actions at the activity level, is conducted within the LAMS to ensure uniformity across all fleet-level users. Once the SECA has issued transfer authority, the losing activity must perform a transfer inspection on the selected items and transport them in a ready-for-issue status to the nearest local supply department within 30 days. If the items cannot be shipped within the standard 30-day interval, a detailed explanation must be presented to the SECA specifying the reason and requesting an extension. The deadline for transmission of a message notifying the SECA of the non-availability of the identified assets is 15 working days from the date that the transfer notification was authorized. If the asset transferred requires a historical record (OPNAV 4790/51) for annotating the usage of the item, then the original copy of that record must also be transferred to the gaining activity. The gaining activity is required to proactively monitor the LAMS for incoming items and to request a survey for in-transit loss if items are not received within 180 days of the transfer authorization. The gaining activity must perform an acceptance inspection on items received; if items are received in any condition other than ready for immediate use, then the gaining activity is also tasked with contacting the SECA for further direction. The return of non-functional items to the point of origin without SECA approval is unauthorized (CNAF, 2008).

### 7. Accountability Requirement

For proper accountability of IMRL assets, inventories must be conducted at certain mandatory intervals. Further inventories during daily usage are recommended but not required under the guidelines of the AMMRL program. All occasions for IMRL inventory must be performed in a wall-to-wall format, so named because the physical location of all items the activity is accountable for must be physically verified (CNAF, 2009). The four requisite intervals for inventory are as follows:

#### *a. Annual Inventory*

Completion of the annual inventory is reported to the SECA and must be done once every calendar year, with the additional restriction that 18 months cannot be exceeded between performances of subsequent inventories (CNAF, 2008).

#### *b. Maintenance Officer Relief Inventory*

The maintenance office relief inventory is conducted as part of the turnover process between maintenance officers and has a completion deadline of 30 days from the assignment of the new maintenance officer. This inventory can be performed in conjunction with the annual requirement, and no outside reporting is required of this inventory unless it is also used as the annual inventory (CNAF, 2008).

#### *c. Work Center Quarterly Inventory*

The work center inventory is performed once each quarter of the calendar year to report the condition of all IMRL assigned to the work center and in its custody. Compliance is the division officer's responsibility and is reported to the maintenance officer (CNAF, 2008).

#### *d. Sub-Custody Quarterly Inventory*

The sub-custody inventory is performed once each quarter of the calendar year to report the condition of all IMRL assets assigned to activities that have been checked out to another hosted activity. Compliance is the responsibility of the maintenance material control officer of the hosted activity and is reported to the maintenance officer of the hosting activity (CNAF, 2008).

## B. TOOLS

The Tool Control Program (TCP) is based on the concept of a family of specialized toolboxes and pouches configured for instant inventory before and after each maintenance action. The content and configuration of each container is tailored to the task, work center, and model aircraft maintained. Normally, tool containers are assigned

to and maintained within a work center. However, if considered necessary and space permits, a tool control center (tool room) may be established (Commander, Naval Air Systems Command, 2004).

There are numerous maintenance actions that may be required to service and repair Navy and Marine Corps aircraft. There could be hundreds of different types of maintenance requirements, each with its own unique set of tools. In addition, space limitations on an aircraft carrier necessitate the use of compact toolboxes containing only the necessary tools required for each specific maintenance action. NAVAIR Lakehurst is responsible for designing and developing customized toolboxes and manuals to accommodate maintenance and tooling requirements for most Navy aircraft and their support equipment. Information is taken from the tool control manuals and used to design toolboxes for specific maintenance tasks listed in the manuals. This eliminates the need for toolboxes containing tools that are not needed, which saves money, time, and space. Each tool has an assigned location within the toolbox to help keep track of all the tools within the box and quickly identify any missing tools. The NAVAIR Lakehurst team is currently working on developing toolkits for a number of Navy aircraft programs, which include the V-22, F-18, T-45, and H-60 support equipment programs (Naval Air Warfare Center, 2010).

### 1. Governing References

The primary reference governing the management of tools used for aviation maintenance purposes is the NAMP. The NAMP functions as a high-level guidance document for the programs it covers. The details of individual programs are governed by specific references that the NAMP indicates for adherence to applicable standard operating procedures. In the case of tools, the NAMP refers readers to the Naval Air Systems Command (NAVAIR) Tool Control Manual series (CNAF, 2009).

#### *a. Naval Aviation Maintenance Program*

The NAMP is sponsored and directed by the Chief of Naval Operations (CNO) and is implemented by Commander, Naval Air Forces (COMNAVAIRFOR). The Commander, Naval Air Forces Instruction (COMNAVAIRFORINST) 4790.2 series

(CNAF, 2009) addresses maintenance policies, procedures, and responsibilities for the conduct of the NAMP at all levels of maintenance throughout naval aviation. It is considered the bible of naval aviation maintenance and takes precedence over all other aviation-related maintenance manuals (CNAF, 2009).

#### *b. Tool Control Program*

The TCP establishes policy and responsibilities for implementing, maintaining, controlling, storing and replacing common hand tools. It is applicable to all Navy and Marine Corps O-level and IMA/commander, Fleet Readiness Center (COMFRC) activities performing or supporting aircraft maintenance. In addition, the TCP applies to all commercial and other government activities that perform contract maintenance, production, or other type of support functions on naval aircraft. The purpose of the TCP program is to assist the warfighter by providing an instant inventory capability through tool containers that have been internally tailored with each specific tool positioned in a unique location. These tool locations are typically silhouetted and provide a quick and accurate method for identifying tools that are missing, because missing tools can cause catastrophic results to aircrew and/or aircraft. The primary objectives of the TCP are to heighten safety by eliminating accidents and equipment damage attributed to uncontrolled tools and minimizing tool-replacement costs. As per the CNAF, an effective TCP is the responsibility of all maintenance personnel at every level of the chain of command (CNAF, 2009).

##### (1) NAVAIR 17, Tool Control Manuals (Series)

The information presented in these NAVAIR 17 manuals includes procedures, methods, and detailed instructions for the operation of the tool control program; the duties of key personnel; materials lists; container identification; and tool container/fixture fabrication instructions, container layouts, and tool inventories. The procedures contained in these manuals have previously proven themselves to be effective and are necessary for the positive control and accountability of tools (Commander, Naval Air Forces, 2009).

(2) NAVAIR 17-1FA18-1

NAVAIR 17-1FA18-1 (Commander, Naval Air Systems Command, 2007) is the *Aircraft Tool Control Manual for all Navy and Marine Corps F-18 Aircraft*. The purpose of this technical manual is to present the TCP for Navy and Marine aviation organizational maintenance activities. The main objective of the TCP is the prevention of the aircraft accidents, incidents, and foreign object damage (FOD) that have been factors when tools were left unaccounted for. Some additional benefits that are realized by compliance with the procedures in the manual are the reduction of pilferage, initial outfitting costs, in-use inventories, tool replacement costs, and maintenance man-hours. The reduction of any of these items makes significant contributions to cost effectiveness (Commander, Naval Air Systems Command, 2007).

(3) NAVAIR 17-1E2C-1

NAVAIR 17-1E2C-1 (Commander, Naval Air Systems Command, 2004) is the *Aircraft Tool Control Manual for all Navy and Marine Corps E2C Hawkeye Aircraft*. It fulfills the same objectives as the F/A-18 series manuals, but for the Hawkeye platform.

### 2. Compliance with these Tool Control Manuals

Compliance with and implementation of these tool control manuals is the responsibility of the respective aviation squadrons who are designated as the aircraft controlling custodian (ACC) and/or the type commander (TYCOM). These requirements are established in Office of the Chief of Naval Operations Instruction OPNAVINST 4790.2 (Commander, Naval Air Systems Command, 2004).

### 3. Responsibilities: O-Level, I-Level, and COMFRC Activities

#### *a. Aircraft Controlling Custodians*

ACCs may designate subordinate activities as tool control model managers for specific type/model/series (TMS) aircraft (CNAF, 2009).

#### *b. The Maintenance Officer/Fleet Readiness Center Equivalent*

The MO/FRC equivalent develops local command procedures, when necessary, which outline a comprehensive, integrated, and monitored TCP in areas where tooling is required for the performance of aircraft, aircraft component, and related equipment maintenance, rework, and installation. (It is during the development of command procedures that any pooling of resources between similar T/M/S aircraft and co-location of resources may be identified; CNAF, 2009.)

#### *c. The Assistant Maintenance Officer/Industrial Training Department*

The assistant maintenance officer/industrial training department provides all the required training requirements on the TCP to all aviation maintenance personnel. In particular, the training provided emphasizes personnel TCP responsibilities and missing tool procedures (CNAF, 2009).

#### *d. The Maintenance Material Control Officer /Production Control Officer*

The maintenance material control officer (MMCO)/production control officer establishes tool control centers, when necessary, and is designated as the approving authority to add, delete, or modify tools. These tool room establishments are usually manned by Sailors from work centers and are not necessarily provided for in the squadron's manpower documents. This can lead to each F/A-18 squadron having its own unique tool room, each carrying similar items of tools/IMRL (CNAF, 2009).

#### *e. The Program Manager/Coordinator*

The program manager/coordinator designates in writing a TCP coordinator/subject-matter expert (SME) and ensures the proper operation of the tool control work center. Additionally, he or she reviews all aviation fleet maintenance (AFM) fund purchases or FRC operations and maintenance/Navy (O&MN) requisitions submitted by the TCP coordinator for the purchase of spare or replacement tools to screen for any unauthorized or excess tool purchases. AFM funds are used to maintain and support the U.S. Navy's fleet of operational aircraft. Other responsibilities of the program

manager/coordinator are to budget and plan AFM funds for O-level aviation activities or O&MN for FRCs in the procurement of approved tool containers and hand tools (CNAF, 2009).

### 4. TCP Implementation

When a tool control manual (TCM) does not exist for a specific T/M/S aircraft, the reporting custodian develops a local TCM and is submitted via his or her chain of command to the cognizant type-wing for approval. All Navy and Marine Corps aviation activities utilizing NAVAIR 17 series TCMs identify the particular tools they require using the tool inventory list that the TCM provides. Intermediate maintenance activities ashore and activities that are not on an established TCM determine the tools necessary to perform repetitive tasks in each work center and develop a local tool inventory list. These lists identify each tool by item number, nomenclature, specific quantity, and national stock number (NSN). Each tool is etched whenever physically possible, including all pieces of a set. This procedure can be very tedious and time consuming when multiple type boxes are designated for a work center. Tools that are too small to etch are identified by an asterisk (*) in the tool container inventory list (CNAF, 2009).

### 5. Tool Containers

All Navy and Marine Corps aviation activities utilizing NAVAIR 17 series TCMs shall establish tool container configurations per the TCM. It is mandatory that all hardware placements, such as clips and brackets, and the drilling of holes are exactly as indicated in the drawings. These tool containers must be numbered with the applicable aviation organization code, work center code, and container number (for example, AC3-110-2). If the work center authorizes more than one of the same type tool container, the additional containers are identified with a numerical suffix (for example, AC3-110-2-1). In addition, the position of each individual tool is silhouetted against a contrasting background to assist in identifying any missing tools and to ensure an accurate inventory. Every individual tool location is numbered with a corresponding number on the tool container inventory list. A copy of the TCM inventory list, TCM diagram, and tool container shortage list is placed and firmly attached within all tool containers so that

they do not become sources of FOD.  A brief explanation of FOD and the dangers it poses is explained at the end of this section (CNAF, 2009).

### 6. Proposed Changes, Deviations, and Additions

The warfighter is encouraged to suggest improvements to the NAVAIR 17 series manuals.  Any proposed changes in the tool inventory and/or container layout diagrams must be sent by technical publications deficiency report (OPNAV 4790/66), with appropriate justification, via the appropriate wing commander and ACC/TYCOM for approval/disapproval.  These procedures are established in the Discrepancy Reporting Program in the NAMP.  Any requests for deviation for activities with unique operational situations and/or more than one type aircraft is submitted, with appropriate justification, via the appropriate wing commander to the ACC/TYCOM for evaluation and/or approval as required (Commander, Naval Air Systems Command, 2004).

### 7. Foreign Object Damage

FOD is defined as a substance, debris, or article alien to the vehicle or system that would potentially cause damage. FOD is any damage attributed to a foreign object that can be expressed in physical or economic terms and that may or may not degrade the product's required safety and/or performance characteristics.  Typically, FOD is an aviation term used to describe debris on or around an aircraft, or damage done to an aircraft (FOD Control Corporation, 2007).

FOD has been a part of naval aviation accidents since the earliest days of flight, whether it was propeller nicks, tire damage, or tears to airframe fabric, but FOD actually started getting the visibility it needed with the introduction of the jet engine. FOD includes loose hardware, extra parts, pieces of runways, pens, coins, garbage, and wildlife.  Basically, anything that can cause damage to an aircraft engine, flight controls, or fuel systems falls under the definition of FOD.  FOD can be found anywhere in the aviation environment, from the runway to the manufacturing plant and hangars.  FOD damage has often resulted in catastrophic events, leading to loss of life and valuable equipment.  The National Aerospace FOD Prevention Inc. estimates the cost of FOD to the global aerospace industry at $4 billion annually.  This sum is due mainly to repairing

aircraft engine damage caused by the ingestion of FOD. The FOD program in naval aviation came into being due to the fact that almost all FOD incidents are entirely preventable (FOD Control Corporation, 2007).

In the following chapter, we will discuss the primary data sources and analysis techniques used in our model.

# III. METHODOLOGY AND REFERENCE DATA

The third chapter of this document encompasses the primary data sources, analysis techniques, and assumptions upon which our analysis of the tool and IMRL outfitting procedures are based. We list methodology that is common to all analysis formats to prevent redundancy when switching between evaluation techniques. We introduce any analysis techniques or assumptions that are peculiar to a specific model in Chapter IV at the same time as the model itself.

## A. DATA SOURCES

The primary resources listed in the data sources section were our informational foundation when constructing this document. The persons listed by name or title are the subject matter experts in their specific area and the publications are the governing reference for their respective discipline. Clarification of assumptions integral to the calculations of this document can be referred back to these sources of expert knowledge for verification of policy adherence.

### 1. Brian Kudrna

The primary point of contact for interface between our project research team and the CVW-5/Marine Activity Group (MAG)-12 Integrated Transition Team for Commander, Naval Air Forces (CNAF)/Commander, Naval Air Force Pacific (CNAP) in San Diego. Kudrna coordinated and consolidated all information requests that were made to gather source data on CVW-5 transition planning. Additionally, he spearheaded our drive to collect cost data for aerospace maintenance materials.

### 2. Raymond D. Wendrzycki

NAVAIR Aircraft Tool Control Program Manager. Wendryzycki provided all Hornet Tool data, including cube dimensions and costs, for all CVW-5 Hornets and fixed wing assets.

### 3. David A. Dougherty

CSFWP IMRL Manager. Dougherty provided all Hornet IMRL data, including cube dimensions and costs for all CVW-5 Hornets and fixed-wing assets.

### 4. CVW-5 Maintenance Officer

Subject-matter expert and decision authority for air wing maintenance planning. Michael Washington provided the research team with information specific to CVW-5 operations and requirements through interaction with Brian Kudrna.

### 5. CNAF Publications

Referenced for regulations and procedures governing the materials used in aerospace maintenance under Navy cognizance.

### 6. Type/Model/Series Publications

Provided information peculiar to the individual classes and variants of aircraft comprising CVW-5.

### 7. NAF Atsugi to MCAS Iwakuni Transition Planning Documents

Provided data relating to the reason, timeframe, and magnitude of the air wing relocation, which we could analyze for planning purposes.

## B. ANALYSIS TECHNIQUES

One of the goals of NAVAIR's "Supporting Sea Power-21" is to reduce the cost of doing business throughout the NAE. One tool is AIR*Speed*, which is a philosophy, strategy and a proven set of tools that enables NAVAIR and the NAE to achieve cost-wise readiness. It is a means of reducing the cost of doing business, improving productivity, and increasing customer satisfaction. The NAE is guided by NAVAIR AIR*Speed*, which emphasizes applying the tools of continuous process improvement to non-production, transactional service environments. Utilizing theory of constraints, Lean, and Six Sigma methodologies, personnel at all levels are improving ways to change how the NAE does business at every level of the organization: headquarters, business unit, department, program office, and integrated product team. Just because a process has been done a

certain ways for years, it does not mean that it must not be under constant, vigilant review. There might be cost savings that could be realized to the NAE if the process were improved or if unnecessary steps were removed. Some of these unnecessary steps that are considered waste in Lean/Six Sigma go by the acronym of TIMWOOD: Transportation, Inventory, Motion, Waiting, Over-Production, Over-Processing, and Defects (Miller, 2007). The analysis, removal, or reduction of any of these seven forms of waste can reduce overall costs, resulting in savings that may be reallocated in a more efficient manner. AIR*Speed* also emphasizes continuous process improvement (CPI), which is another tool that is often used to fix problems; it is easily available to all personnel and can deliver significant benefits (CNAF, 2012). The use of many of these AIR*Speed* methodologies in this analysis may assist decision-makers in determining the best course of action on whether CVW-5 should procure a duplicate set of tools (IMRL) or whether there is a better mix of alternative actions. Figure 11 depicts the seven wastes known by the acronym TIMWOOD.

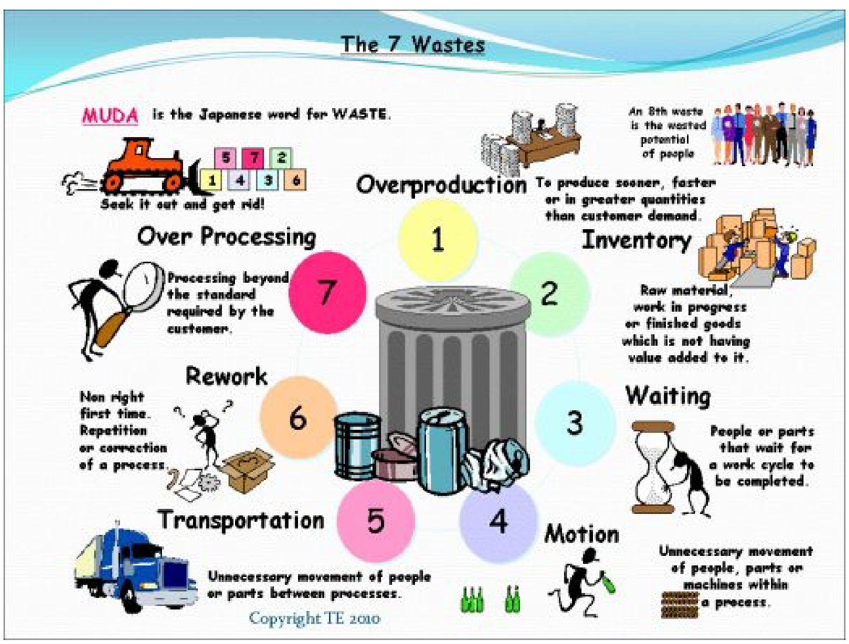


**Figure 11. Chart of TIMWOOD**

(Google, 2012)

### 1. Valuation of Duplicated Assets

The valuation of a duplicate set of tools and IMRL assets for carrier-deployed usage by CVW-5 can be viewed from both qualitative and quantitative perspectives. Neither viewpoint can decisively conclude the correct equipage level for the air wing, but the valuation to stakeholders under the represented categories provides a framework in which a purchasing decision can be empirically approached.

#### *a. Monetary Criteria*

The most concrete criteria from which to make a decision from a business perspective are monetary, but the results gleaned from financial analysis can be difficult to quantify in the public sector (Arsham, 1994). Although the goal of most private-sector ventures to produce a return on investment greater than the invested capital can be clearly measured and compared to benchmarks, the success of public enterprises defies such clear-cut valuation (Rainey, 1983). Public-sector institutions seek to reduce costs while still delivering an expected level of service to their benefactors (Rainey, 1983). The savings in transportation costs does go a long way in defining the time period necessary to produce a return on investment from an investment in additional tool and IMRL items, but for a full valuation of the supplementary assets to the air wing, additional attributes must be considered.

#### *b. Ease of Use*

The ease-of-use factor for multiple sets of IMRL and tool assets considers the dividends resulting from reducing the man-hours necessary to pack and transport assets from one location to another several times throughout the year. By purchasing an entire or partial duplicated set of maintenance materials for each location, man-hours will not have to be expended at the beginning and end of each deployment cycle to prepare the site-specific assets for transportation. The transportation of the items does not increase their value in any way and should, therefore, be considered waste (Six Sigma Service, 2006). The newly available time that was previously used for pack-up can now be devoted to value-added activities, such as professional development of the maintenance workforce or upkeep of squadron spaces.

However, if additional assets were to be purchased and stored during periods of non-use, additional labor would be expended in cataloging, preventative maintenance, and general upkeep of the added items. There are two methods in which the time devoted to upkeep of additional assets could be recorded. One option is that the man-hours necessary for this upkeep could be deducted from the time savings proposed in the previous paragraph and considered a cost due to the additional work generated by a change in the authorized equipment allotment. An alternate viewpoint would be to consider this additional labor as value added because it would contribute to enhanced readiness by making the necessary maintenance aids available at their intended point of use.

#### *c. Spare Parts*

The benefit of having a duplicate set of assets available for maintenance in the event that the primary assets were unavailable due to scheduled maintenance, such as a calibration, or in the event they were to simply fail, can be approached from the standpoint of operational availability. The predicted operational availability of a system can be broken down into two components: the mean time between failures (MTBF) and the mean down time (MDT). The MTBF represents the reliability of the system because it quantifies the duration of failure-free operation that the system can provide under specific conditions (Chief of Naval Operations, 2003). The MDT puts the amount of time the system is unavailable, or downtime, into quantitative terms (Chief of Naval Operations, 2003). The mathematical relationship between these terms is shown in the following equation: $A_o = MTBF/(MTBF + MDT)$ (Chief of Naval Operations, 2003).

The MDT itself is composed of two characterizations of time, the mean time to repair (MTTR) and the mean logistics delay time (MLDT; Chief of Naval Operations, 2003). The MTTR is an average measurement of the time it takes to return the system to an operational status if all the materials and resources necessary for the repair action are present and available (Chief of Naval Operations, 2003). The MLDT, on the other hand, is an average measure of the time to procure the necessary resources for the proposed repair through the applicable logistics support system (Chief of Naval

Operations, 2003). The relationship between these terms is represented by the equation: MDT=MTTR+MLDT (Chief of Naval Operations, 2003).

Finally, the MLDT can be further decomposed into the mean supply response time (MSRT), the mean administrative delay time (MAdmDT), the mean down time for training (MDFT), the mean down time for documentation (MDTD), and the mean down time for other reasons (MDTOR; Chief of Naval Operations, 2003). Of these terms, the one of primary concern within the scope of this thesis is the MSRT because it represents the average amount of time the system is down per maintenance action due to procuring both the spare and replacement parts necessary for the task (Chief of Naval Operations, 2003). This measurement takes into account procurements from both onboard the ship/station and those that are referred to another activity for completion. The paramount importance of this concept is proven by the reality that the MSRT is overwhelmingly the largest driver of MLDT and, therefore, has more impact on operational availability than any other cause (Chief of Naval Operations, 2003, p. 75).

#### *d. Enhanced Readiness*

An increase in spare IMRL and tool assets contributes not only to an increased availability for those items, but also, and more importantly, to the ability of the supported air wing to execute the missions and training exercises to which it has been assigned. However, this enhanced readiness is predicated on the assumption that the assets assigned in enhanced numbers are essential to maintenance actions on the air wing's aircraft. Care must be taken when determining which assets, if any, are to be duplicated so that superfluous items that are not required for routine maintenance are not purchased in quantities greater than necessary to achieve their expected benefit. The correct estimation of this utility is facilitated by the fact that the air wing operates as one unified team rather than as a disconnected collection of discrete assets. Although an item can be proven to be used only infrequently over the course of a standard year and, therefore, is delineated as a non-common use item, it cannot be eliminated entirely from the material equipage authorized to the air wing as a whole. However, it can be designated as an item that will become the responsibility of one squadron that then sub-custodies the asset to other activities under local guidance. This sharing of material, if it could be accomplished

at the local level without off-station authorization for individual transactions, has the potential to enhance operational effectiveness while also reducing asset line-item requirements.

#### *e. Prevention of Damage*

An indirect result of moving the large CVW-5 IMRL and tool equipage from homeport to the deployment platform multiple times throughout the year is that it is exposed to excess wear, above and beyond what it was designed to withstand. On every occasion that the material in question is packed, unpacked, or physically removed from its present location, there is a possibility, however remote, that it may experience some form of damage during the transit that it would have been immune from if it had been left in its original location. Due to the addition rule of statistics represented by the equation P(A or B) = P(A) + P(B) – P(A and B), the very small probability of damage that the assets are exposed to in each aspect of the transportation process will gradually accrue into a larger probability of damage occurring to the items at some unknown time in the distant future (Buchanan, 2010).

This concept can be more plainly expressed by the relationship between random independent events. If the probability of two discrete events occurring is low and the researcher is interested in the probability of both occurring, then the probability of the two events would be multiplied and the resulting probability would be smaller than either of the two original probabilities. For example, the probability of rolling a six-sided die and getting a three is one in six (1/6). If this exercise were repeated twice, then the probability of getting a six on both of the rolls would be the product of each separate roll or 1/36, a much smaller probability. Conversely, if the experimenter is interested in the probability of at least one six from either roll, then the result would be 1 - (5/6)(5/6) = 11/36, which is a larger probability than either individual outcome alone.

The theoretical underpinnings of the die-rolling example can be directly transferred to the subject matter of this project in which the probability of damaged equipment takes the place of a roll of the die. Through procurement of multiple sets of

tool and IMRL assets, transportation cycles of the assets will be greatly reduced, and with this reduction will come an attenuation of the risk associated with movement.

#### ***f. Morale***

The duplication of a portion of the IMRL and tool holdings of the air wing with the intention of reducing the amount of transport between operating locations could increase the morale of the workforce because it would eliminate repetitive actions that do not add value in the process. The target of such an increase in morale would be a decrease in the defects that Sailors introduce to the process through a lack of ownership, which is induced by the reduced quality of life they experience when spending extra time on duty to repetitively pack and unpack items multiple times during the year. To explain how the morale of the Sailors performing the actual labor associated with the movement of material could be improved through the purchase of supplementary assets, it is first necessary to describe how workers derive satisfaction from their work efforts. Subsequently, the reasoning behind why the workers believe working conditions that have existed in the past will continue at the present level, or will improve in the future, can be addressed.

The motivational framework pertinent to explaining the impact on morale by the actions of management in this application is the Job Characteristics Model, which was developed by Richard Hackman and Greg Oldham (Ramlall, 2004). The Job Characteristics Model examines motivation through the interaction of psychological states and job characteristics to determine how to explain to the observer in what way the task itself is instrumental to affecting the motivation of workers. Of the three possible psychological states available under this framework (experienced meaningfulness, experienced responsibility for outcomes, and knowledge of the actual results), the state of experienced meaningfulness has the most bearing on worker morale as influenced by the elimination of non-value added activities (Ramlall, 2004). The experienced meaningfulness of the work would be an attribute specific to each Sailor or worker in the endeavor and, therefore, would vary from person to person. By extension, a reduction in motivation could be expected on the part of the workforce if workers perceived the shuttling of materials back and forth to standard operating sites as wasted effort, as has

been posited earlier in this thesis, and with that reduction in motivation could arise a corresponding reduction in effort (Kidwell & Martin, 2005). Management could implement a program to increase the perceived task significance on the part of the workers in the event of such a reduction of experienced meaningfulness and expressed effort, but the application of such a plan is beyond the scope of this thesis, which will focus on the instillation of a high level of morale through an elimination of non-value added transportation activities.

The unwritten and implied promises made to workers about the support that will be provided in the performance of their jobs are a form of social contract (Rousseau, 1995). Both management and the workforce must respect these agreements to enable business transactions to proceed (Rousseau, 1995). By the same logic, if an organization's success and, therefore, its existence are dependent on achieving certain goals, then the workforce must understand that its management is actively pursuing policies that move the collective towards those goals. In a different form, the objectives that management sets down lead to pressure for perform on the part of the worker, but these objectives also can be interpreted as a contract for support on the part of management (Obolensky, 2010). The stated goal of an operational military squadron is combat readiness; therefore, the members of that squadron have a reasonable expectation that their efforts are directed toward activities that will improve the readiness of the squadron. For the purposes of this thesis, the contractual obligation senior leadership has to the workforce in regards to morale is to provide tools and IMRL in a manner consistent with improved readiness.

### 2. Upkeep/Preservation Personnel for Unused Assets

The procurement of additional tool/IMRL items requires additional manpower to perform preventative maintenance on the assets, as well as to maintain them in a useable status when the remainder of the air wing has departed from the ship. The additional manpower will be provided through an augment to the joint upkeep detachment, which the air wing establishes from temporarily assigned personnel provided by each of the component squadrons for maintenance of shipboard compartments during extended in-port periods. The working supposition is that no additional maintenance personnel will be provided by the Bureau of Navy Personnel to accomplish the preservation of the

additional assets as the additional man-hours required to do so can be realized though tighter management and repurposing of the currently authorized squadron workforce.

### 3. Cost Benefit Analysis

The cost benefit analysis presents a consideration of five major factors that shape the life-cycle ownership costs of maintenance assets over a 20-year period. By manipulating these variables independently, we can glean insight into how to structure the support package for effective and efficient operation.

### 4. Risk Analysis

Risk analysis is performed to represent how multiple transportation evolutions can impact the ownership costs of a maintenance support package in ways other than the cost of the transportation itself. Oracle Crystal Ball simulation software is used to project the data over thousands of iterations so the true probability can be estimated.

## C. ASSUMPTIONS

### 1. Frequency of Carrier Deployments

The champion of our research is Brian Kudrna, the Carrier Air Wing Five (CVW-5)/Marine Activity Group (MAG)-12 Integrated Transition Team Coordinator for CNAF/CNAP in San Diego. He recommended the use of a base estimate of four annual round-trip movements of equipment to the forward deployed naval forces (FDNF) aircraft carrier by CVW-5. The direction of the movement would be four transportation cycles for embarkation of assets prior to the ship getting underway, and four cycles of disembarkation upon return of the vessel to homeport. The number of transport cycles is necessary for generating a cost estimate relevant to the number of years required to deliver a return on investment for additional purchases of tool and IMRL assets. If the number of evolutions where equipment were moved back and forth to the ship for deployment were to increase and/or decrease, then the payback estimates would vary accordingly.

In addition to the routine deployments (both scheduled and unscheduled) that the united FDNF carrier and air-wing team undergo, there are additional deployment requirements that the air wing undertakes during the inter-deployment readiness cycle

(IDRC), which does not necessitate travel to the carrier but does require the transportation of IMRL and tool assets to the point of use. These additional detachments do not generally call for the presence of the entire air wing, so the equipage authorized for each squadron is split between the mobilized element and the component of the squadron remaining in homeport. Examples of these mobilizations would be the Strike Fighter Advanced Readiness Program (SFARP), which is used to prepare operational squadrons for deployments in which they coordinate the usage of weapons by sea-, air-, and land-based assets; or Cobra Gold, a six-week exercise conducted jointly with the Royal Thai Armed Forces (U.S. Army, Pacific, 2012). Because these operations do not involve the FDNF carrier, where the additional tool and IMRL assets would be located between joint deployment cycles, they can be discounted from the number of mobilization evolutions leading toward the duplication of assets, from a transportation-cost perspective. The assets would not be involved in exercises such as the ones previously mentioned in this paragraph. CVW-5 fixed-wing assets would be supported by current assets, which would involve usage of the same level of transportation funding under either scenario. However, if the air wing were to get underway with the FDNF carrier for any additional unscheduled operational commitment above and beyond the currently planned four round trips, such as a humanitarian assistance or disaster relief mission, or an emergent regional security issue, then the cost savings gleaned from not having to transport the second pre-positioned IMRL and tool allowance would be spread over an additional evolution and would serve to quicken the return on the initial outfitting expenditure.

### 2. Carrier Location

The FDNF carrier and air-wing team has a unique operating challenge in that its standard supply chain stretches further than any other capital asset, by definition and due to the location in which the team is homeported (Commander, United States 7th Fleet, 2012a). All other aircraft carriers and carrier-deployable squadrons are located in major fleet concentration areas where there is at minimum one other similar class of ship or T/M/S of aircraft permanently assigned (Pike, 2012). This localization of similar resources in the same geographic area leads to great economies of scale where multiple activities can be supported from a common pool of IMRL items and tools. The FDNF

activities cannot draw on this pool of assets because their material entitlement is a "one-of" entity. By duplicating some or all of the IMRL and tool assets authorized to this air wing, there would be an enhanced readiness due to the availability of additional assets within the assigned geographic area of responsibility (AOR) so that the air wing would not have to contact units in the continental United States for asset replacements. However, the duplication would increase investment in assets that would be used less frequently than in other homeports.

### 3. Air Wing Location

CVW-5 is currently homeported at Naval Air Facility (NAF) Atsugi, Japan, but is scheduled to transition to operations at MCAS Iwakuni, Japan, by 2014 (Singh, 2011). As we discussed in Chapter I, the relocation of the air wing has been proposed for many years, and even after it was approved the execution date has been modified for a more lenient target of 2016. The driving distance from the current CVW-5 homeport of NAF Atsugi to CFAY Yokosuka, Japan, where the FDNF carrier USS *George Washington* (CVN-73) is homeported is 35 miles. The driving distance to CFAY Yokosuka from MCAS Iwakuni is a much larger distance of 542 miles. Although the move is a planned and not an executed event, in this thesis we focus on MCAS Iwakuni as the home of the air wing for distance calculation purposes, as the initial impetus for IMRL and tool duplication was sparked by the deployment challenges posed by the additional distance between the air wing and its deployment platform.

### 4. Air Wing Composition

An air wing consists of four E/F Hornet series aircraft squadrons, and the tool allocation for each squadron is identical, and for practical purposes they are each assigned the same number of aircraft (12). Although some squadrons list the assignment of 13 aircraft, maintenance assets are only assigned on the basis of 12 aircraft due to the rolling requirement for one of those aircrafts to be out of reporting for depot-level repairs at all times. Due to the mirroring of assets between different squadrons of the same T/M/S, computations done in this project are based on the equipage numbers for one full

Hornet squadron. To achieve the impact of transportation-specific maintenance support asset costs for all the Hornets in the air wing, the output numbers are scaled up accordingly.

### 5 Transport Medium

The transportation medium we selected as the standard for the calculations in this thesis is based on the suggestions of Debord, Coleman, and Hodge (2011) in their thesis, which targets the best value analysis of movement strategies for CVW-5 from Iwakuni to Yokosuka, Japan. In their project, they compared multiple options of personnel and equipment transportation within the general categories of sea, air, and ground material handling (Debord et al., 2011). Although they immediately discarded some options as being unfeasible due to regulatory concerns, they retained others for further analysis to determine which was the most economically viable under a broad spectrum of scenarios (Debord et al., 2011). Debord, Coleman, and Hodge (2011) did not advocate any "silver-bullet" solution that offered the best characteristics of price and convenience in the final conclusions of their thesis, so in this thesis we selected surface trucking as a standardized basis for calculating transportation costs.

Although the actual method of transportation is of vital importance for implementation purposes, its selection is beyond the scope of this thesis. The transportation method is only pertinent to this analysis in that it serves as a basis to allocate the largest portion of the cost penalty from operating with a single set of IMRL and tool assets. By standardizing the transportation option between alternative tool and IMRL purchasing scenarios, we perform meaningful cost-benefit analyses from a perspective that is standard throughout the exercise, as any variation in results can be attributed to the configuration of the materials transported rather than to the transportation method itself.

### 6. Storage Availability for Additional Assets

Our operating assumption regarding any additional tool or IMRL assets that could potentially be purchased in response to the recommendations of this research is that these assets would be provided storage space to remain on the FDNF carrier during periods that

the ship was in port and the air wing was disembarked to its homeport. We base this assumption primarily on the consideration that the majority of the payback criteria we propose in this thesis relies on concessions gained from the prevention of transportation in order to calculate the efficiencies that would be earned from the purchase of additional assets. By transporting any supplemental assets to MCAS Iwakuni, rather than leaving them in permanent squadron spaces on the ship, the factors that were previously considered as benefits would shift places on the balance sheet to become additional costs.

The argument could be made to store the supplementary assets at another storage location on Yokosuka base, but that would not be a feasible location due to the crowded nature of the base. Previous attempts to store IMRL items assigned to the USS *George Washington*'s ground support equipment (IM-4) division in facilities on CFAY Yokosuka during periods of scheduled selected restricted availability for shipboard maintenance have been met with strong opposition because the base does not have sufficient storage capacity to hold material in a climate-controlled location. The IM-4 assets in the anecdote above were eventually stored on the flight deck of the carrier for five of the worst weather months of the year. When the material was returned to its storage location, it was below par and caused considerable problems during the air wing's next operational period.

A more realistic but still unfavorable scenario for storage, if the material were not retained on the ship, would be to transport the additional assets to NAF Atsugi for storage in one of the hangars, which would be vacated by the homeport transition of CVW-5 to MCAS Iwakuni from NAF Atsugi. Although the space would be available and the transportation costs and time to complete the transfer from Naval Air Station (NAS) Yokosuka to NAF Atsugi would be much less than to transfer to MCAS Iwakuni, there would still be costs associated with the move and wear and tear on the equipment, which would considerably accelerate the need for replacement.

For these reasons, we base all estimates of cost savings in this thesis on the assumption that, if additional tool/IMRL assets were to be purchased, they would be stored on the air wing's primary deployment platform.

# IV. QUANTITATIVE ANALYSIS

The purpose of this chapter is to serve as the quantitative portion of the research project where we analyze data gathered on the cost environment of an operational air wing through the usage of two analytical frameworks with the objective of providing a numerical component to the end recommendation of how the FDNF air wing should be outfitted for maintenance support assets considering their upcoming homeport change. The first framework we discuss is an analysis of how multiple transportation evolutions can impact the ownership costs of a maintenance support package in ways other than the cost of the transportation itself. We use Oracle Crystal Ball software package to project the data over thousands of iterations so that the true probability can be estimated. In the second framework, we present five major factors that shape the life-cycle ownership costs of maintenance assets over a 20-year period. By manipulating these variables independently, we can glean insight into how to structure the support package for effective and efficient operation.

## A. THE RISK OF TRANSPORTATION

### 1. Objective

The objective of this section is to consider alternative tool/IMRL equipage methods of reducing exposure to risk of damage by balancing the transportation costs between ship and shore against the potential damage that comes through transporting assets. The overriding consideration is to ensure that maintenance requirements can be met effectively and efficiently both when home based and when embarked on the aircraft carrier under all scenarios. We explore how costs may vary by first dividing the items that would be transported into five categories according to their general susceptibility to damage. The risk of any one item from the category being damaged while being transported is very small, but that risk, expanded to include the many CVW-5 assets being transported a minimum of eight times each year (four times to the ship for deployment and four times back to homeport after the exercise is complete), eventually compounds into a large probability that one or more items get damaged, destroyed, or lost. The cost may be

derived by using a weighted average of the values of all the items in that category that the air wing owns and operates, assuming that no object in the category has a greater chance of being damaged than any other. We can use the product of this analysis in conjunction with other transportation-related cost data to determine the most advantageous course of action for CVW-5 F/A-18 series asset support.

### 2. Assumptions

We list the general assumptions that cover our risk of transportation and life-cycle costs models in Chapter III, wherein the assumptions are specific to a risk analysis of the factors impacting transportation. We have aggregated the data to damage incurred to one Hornet squadron, and we can extrapolate the values obtained to describe the total Hornet assets in the air wing.

#### *a. Tools and Individual Material Readiness List*

Tools and IMRL items can be separated into five broad categories according to their susceptibility to damage. The categories for the maintenance support assets, along with their proportion of the total allowance by quantity are hand tools (50%), fragile hand tools (20%), power tools (12%), electronic test sets (10%), and calibrateable items (METCAL; 8%). The maintenance-support assets that are more subject to damage are also, on average, the higher dollar-value assets. For example, a socket wrench that falls under hand tools is much less expensive and also less likely to be broken during transport than a torque wrench, which falls into the METCAL category. These are estimates based on discussions with six maintenance officers representing over 40 years of combined experience both at the work center level, where tools and IMRL are ordered, and the maintenance control officer level where funds are obligated.

#### *b. Damage During Transport*

Damage during transport also includes other negative scenarios, such as pilferage or voiding calibration through mishandling or vibration.

#### *c. Traffic Accident Rate*

The accident rate that we utilize in this project is intentionally framed as a worst-case scenario. Although actual accidents vary in severity, all accidents are assumed to be of the same magnitude for our research purposes: total loss. We further assume that the government alone would bear the material loss that would result from a catastrophic traffic accident. The costs due to loss of equipment in a highway accident are solely from the cost of the aviation maintenance assets themselves. Personal injury and property damage to other parties is beyond the scope of this project.

### 3. Methodology

The number of trucks required to transport the entire CVW-5 maintenance material equipage is 24. We consider just the five trucks needed for the amount of material to be transported for one Hornet squadron. The squadron being transported is authorized a total of 4,311 items of tools and IMRL assets distributed among the five transport trucks with the same proportion per truck as that category comprises in the overall proportion of assets listed in assumptions.

### 4. Building the Model

We gathered data on the five categories regarding maintenance assets with the objective of describing the distribution of the data. With the data of the mean and the standard deviation of the damage incidences in each category due to transportation side effects, such as mishandling, packing, and vibration on a truck, we estimated the parameters needed for a probability of damage risk distribution. In the interpretation of our analysis, these damages are expressed as failure rates. We selected the Weibull probability distribution because it is one of the most commonly used distributions in reliability engineering because of the many shapes it can attain; thus, it closely fits the requirement we have for modeling failure rates (Kececioglu, 1991). The parameters needed for a Weibull distribution are the location, the shape, and the scale of the distribution. In this circumstance, we used an approach called the method of moments; this is used to move from the mean and the standard deviation to the shape and scale parameters. A detailed explanation of how to estimate the parameters of a Weibull

distribution with the method of moments approach can be found in the scholarly paper written by Mohammad A. Al-Fawzan, “Methods for Estimating the Parameters of a Weibull Distribution” (Al-Fawzan, 2000).

Once we had the parameters for the Weibull distribution, we created a simulation using Crystal Ball for each trip and for each year per category of tools, for a total of 800 iterations. Then we multiplied the failure rate per trip of a particular category with the total number of tools for that category and divided by 100 in order to get the number of tools that were damaged on each trip. The total number of tools for each category was based on the approximate number of tools per load.

We summed all the failures per trip per year to estimate the number of failures over the 20-year period. These results forecast the distribution of failures over the 20 years for each category. With a Crystal Ball simulation, these forecasts showed the average failures per category, and we used it to know how many tools were going to be damaged for any period of time. We also determined the cost of these failures by multiplying the total failures of a given category with the cost of replacing each unit. We added these costs to estimate the distribution of the total cost of the damages over the 20-year period. With a simulation, this forecast showed the average cost of the damages, which we may use to determine the operating cost for any period of time.

### 5. Accident Rates

Additionally, to control the rates of tools failing due to the transportation, we also considered losses resulting from possible traffic accidents. We collected the information on yearly accident rates in Japan on roads similar to those used to transport tool/IMRL assets. For example, in 2002, out of 79 million vehicles in Japan, 933,828 vehicles were involved in an accident, which leads to a rate of 0.012 accidents per vehicle. This rate is true for most of the years in the period 2002–2011. In 2006, the highest rate of 0.015 accidents per vehicle was registered in Japan; in 2007, the lowest rate of 0.004 was registered (Japanese Ministry of Internal Affairs and Communications, 2012).

We assumed that accident rates follow a triangular distribution with the minimum of 0.004, maximum of 0.015, and likeliest of 0.012 accidents per vehicle. We chose the

triangular distribution because it is known to be useful when the actual distribution of a random variable cannot be determined, especially when the data are too expensive or difficult to collect (Glickman, 2008). Because this is the annual rate, in our model we created 20 iterations for each truck. We assumed the chance of an accident for one truck does not depend on the chance of the accident of other trucks; thus, the events of accidents are independent. The total expected number of trucks that have an accident was calculated as the sum of all 20 iterations for all five trucks.

Accidents can be of different degrees of severity, which may cause different levels of damage to transported tools. As mentioned before, we considered the worst–case scenario of the most severe accident, wherein all tools are damaged and irrecoverable. Knowing the prices for each tool and the total expected number of trucks that would have an accident, we forecasted the cost of the damage due to traffic accidents.

We can consider the above information in the decision-making process, regarding the total dollar amount needed to maintain the required level of tools supply for our units, or in order to calculate the maximum amount to be paid to insurance companies to protect against this risk.

### 6. Interpretation

Figure 12 shows the total costs of damage for the whole equipage of tools in the air wing when transported eight round trips per year for 20 years. The chart incorporates the total number of expected failures for each class multiplied by the average replacement cost for that category. The damage modeled here is only attributable to normal transportation damage such as mishandling, packing and vibration on a truck, etc. Notice that expected loss due to transportation is close to $3.3 million with very little variation from this amount.

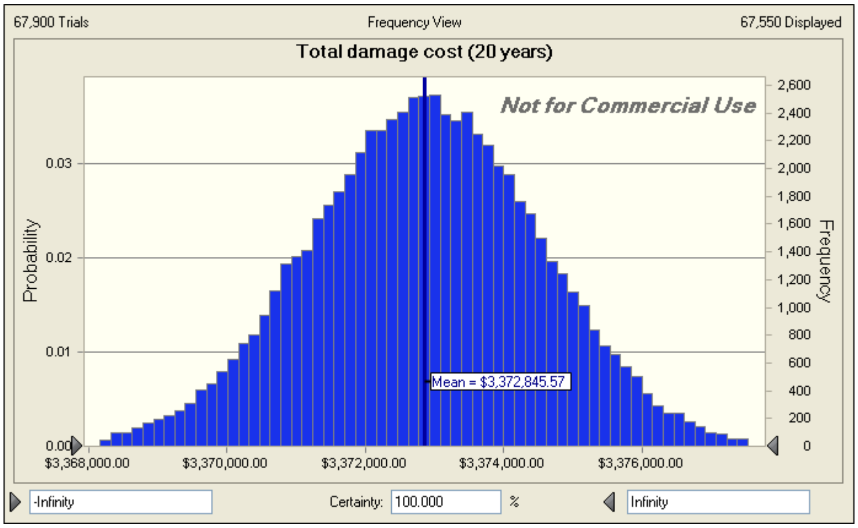


**Figure 12. Total Damage Cost After 20 Years**

Figure 13 depicts the amount of damage that would be incurred strictly because of traffic accidents over the 20-year term of our analysis. We used a 95% level of certainty as a measure of risk to estimate this cost. As this analysis is a value at risk assessment, it is a quantile assessment of the risk due to accidents. The way the chart would be read is at a 5% risk; the value of the accumulative damage is $1,919,463 for one Hornet squadron over 20 years. The damage value to all the Hornet squadrons in the air wing is $7,677,852.

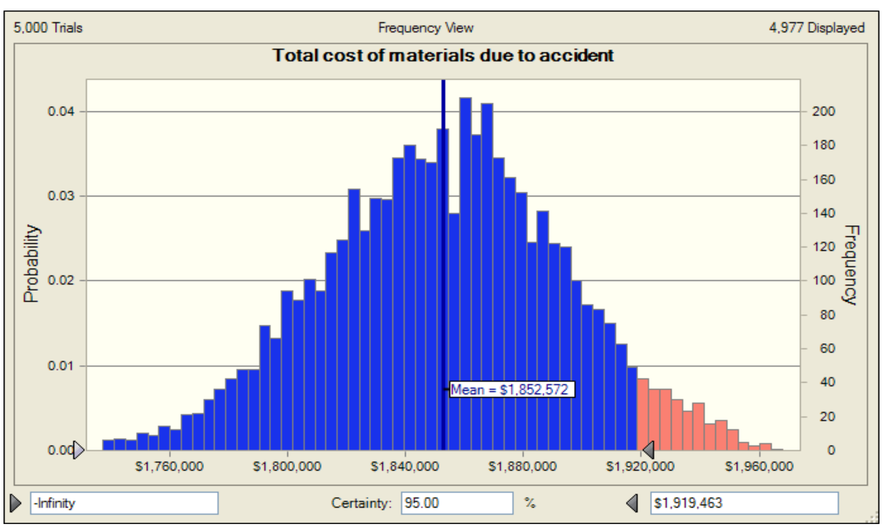


**Figure 13. Total Cost of Materials Due to Accidents**

Figure 14 is a tail value at risk assessment, or a conditional probability assessment based on 5% quantile data. We produced the chart by filtering the outcome of the value at risk assessment to cover only the range greater than $1,919,463. The outcome is the absolute worst-case scenario that should be protected through procurement funds to the amount of $1,935,531 for one Hornet squadron and $7,742,124 for all the Hornet squadrons in the air wing.

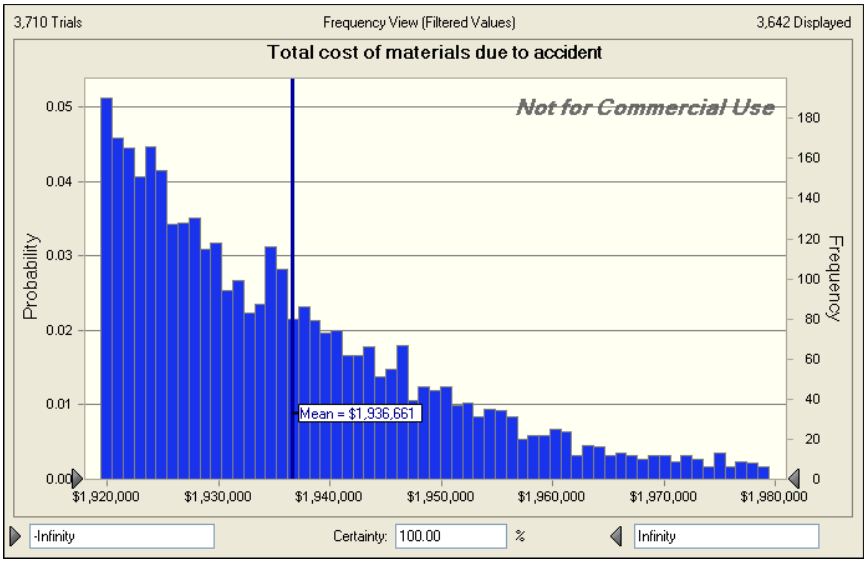


**Figure 14. Total Cost of Materials Due to Accidents (Tail Value at Risk)**

## B. LIFE-CYCLE COST ANALYSIS

### 1. Objective

The objective of this sensitivity analysis is to consider alternative tool/IMRL equipage methods to reduce total equipment ownership costs by balancing the transportation costs between ship and shore with the decision to purchase supplementary assets. The overriding consideration is to ensure that maintenance requirements can be met effectively and efficiently both when home based and when embarked on the aircraft carrier under all scenarios. We explore how costs can be varied by manipulating discrete

input variables to determine the most cost-effective course of action over a 20-year period. Through this analysis, we aim to determine the most advantageous course of action for CVW-5 F/A-18 series asset support.

### 2. Assumptions

We list the general assumptions that cover both models in Chapter III, highlighting the assumptions that are specific to the factors influencing total maintenance support asset life-cycle procurement costs. We aggregated the data to isolate asset requirement costs for one Hornet squadron, and we extrapolated the values to describe the total number of Hornet assets in the air wing.

#### *a. Individual Material Readiness List*

IMRL assets are estimated at a set value of $20,091,955 for each operational Hornet squadron.

#### *b. Transporting Items*

When items are transported, it is estimated that the process damages, destroys, or voids the calibration of 1% of the items during each trip. This is a pessimistic estimate of the damage, assuming a worst-case scenario based on the authors 40 years of combined experience in aviation maintenance at both the work center level where they order the items to the Maintenance/Material Control level where the funds are expended.

### 3. Methodology

In our simulation, only one variable is changed per dynamic scenario; all other factors are held constant to isolate the impact of modifications to the tested value. The input variables which were modified for analysis are: **discount rate**; **currency exchange rates used on transportation procurement**; **quantity of assets duplicated; levels of asset quantity from pooling resources between Hornet squadrons; op-tempo measured by adjusting the number of scheduled and unscheduled deployments.**

### 4. Baseline

The baseline scenario against which all other scenarios were compared was the proposed scenario in which a full duplication is done for all IMRL and tool assets for each

of the four Hornet squadrons in the air wing. The calculation of this value is the least dynamic because the time-value of money does not come into play. Under this scenario, as with all of the evaluated options, one set of tools must be purchased for the squadron as a start-up allowance. The difference between this situation and the others is that a second maintenance package is purchased at year zero, precluding the transportation of assets that year or any other year. The only costs that are incurred during this scenario are for the purchase of the initial outfitting requirement at double the standard level. The analysis does not take into account the replacement of any tools broken through normal use under this scenario, because that is a factor that would occur across any scenario and can therefore be discounted from cost-benefit calculations. For example, if the squadrons had two sets of maintenance accessories, each of which was used half of the year, then they could reasonably be expected to break, in aggregate, as many assets from the two sets as they would if they were only using one set of assets for the entire year. A separate figure that is germane to the discussion is the percentage of assets that is broken during transportation, if a full or partial set of assets is required to be physically moved from one operating location to another. Under the model governing the remainder of our scenarios in this section, the breakage value would fluctuate depending on the number of trips required and on the percentage of assets transported each trip.

It is important to note that, in addition to the routine deployments, both scheduled and unscheduled, that the united FDNF carrier and air wing team undergoes, there are additional deployment requirements that the air wing undertakes during the inter-deployment readiness cycle (IDRC) that do not necessitate travel to the carrier but do require the transportation of IMRL and tool assets to the point of use. An example of this type of mobilization is Cobra Gold, a six-week exercise conducted jointly with the Royal Thai Armed Forces. Because these operations do not involve the FDNF carrier, where additional tool and IMRL assets would be located between joint deployment cycles, they can be discounted from the number of mobilization evolutions leading toward a justification of the duplication of assets from a transportation perspective. This analysis is

because the additional assets would not be involved in the exercises listed previously; the non–carrier-based exercises would be supported by existing assets that are currently transported to all operating regions.

### 5. Dynamic Scenarios

The scenarios represented in this section have a single variable that is altered to yield the life-cycle cost of the support package under alternate input conditions. We can then compare the resulting output against the baseline as a foundation for a quantitative cost-benefit analysis.

#### *a. Operational Tempo*

The operational tempo (OPTEMPO) could impact the life-cycle cost of the enterprise by resulting in extra transportation costs for each additional movement evolution to or from the ship. If the air wing were to get underway with the FDNF carrier for any additional unscheduled operational commitment above and beyond the currently planned four round trips, such as a humanitarian assistance disaster relief mission or an emergent regional security issue, then the additional expense of having to transport the sole set of tool and IMRL assets would be applied in its entirety to more evolutions. Consequently, the more deployment evolutions that are executed, the less attractive the lower initial cost of utilizing a single set of maintenance assets appears over time.

Conversely, if fewer trips between the deploying platform and the air wing's homeport shore facility are executed in a given year, then the life-cycle ownership costs will decrease from the level projected for a higher deployment requirement. It is important to note that the decrease in the life-cycle ownership costs from such a reduction of deployment evolutions does not drop below the magnitude of the baseline of duplicated assets until the annual number of trips drops to four, signifying only two shipboard deployments in a year. Such a low deployment OPTEMPO is unrealistic for the Navy's only forward deployed aircraft carrier, and leads to the notion that maintenance material purchasing decisions cannot be justified strictly from artificially varying the air wing OPTEMPO.

Table 1 applies actual numbers to the concept that more deployments will result in higher life-cycle ownership costs than fewer deployments due to the variable costs of transportation and breakage associated with moving a large number of assets overland. The relationship between the number of trips in a given year and the life-cycle cost overall is also proven to be directly linear because the addition or subtraction of two additional transport evolutions, or one round trip deployment evolution, always results in a corresponding increase or decrease of $29.2 million.

**Table 1. Scenario Summary Due to Change in OPTEMPO**

| Scenario Summary | | | | | | |
|---|---|---|---|---|---|---|
| | Current Values: | 2 Trips | 4 Trips | 6 Trips | 10 Trips | 12 Trips |
| **Number of Trips** | 8 | 2 | 4 | 6 | 10 | 12 |
| **Life Cycle Costs ($M)** | 197.7 | 110.1 | 139.3 | 168.5 | 226.9 | 256.1 |

#### ***b. Partial Duplication***

The next variable that we examined was how the percentage of IMRL and tool assets for which a duplicate set was purchased impacted the total life-cycle costs. The method we used to obtain these values was to vary the amount of maintenance materials, of which two copies were obtained, in increments of 25% to determine whether there was any relationship between quantity purchased and costs incurred. As seen in the chart below, there is a negative correlation between the quantity of material purchased and the cost incurred over a projected 20-year useful life of the assets. The two figures consistently move in opposite directions; an increase in the amount of assets duplicated is rewarded by an analogous reduction in overall life-cycle costs.

Table 2 demonstrates that by increasing the quantity of assets duplicated and by extension the initial material costs, the additional funds that must be obligated to meet this raised level of material coverage is more than offset by the decrease in transportation fees and costs due to damage over the period of the investment.

Table 2. Scenario Summary Due to Change in Partial Duplication

| Scenario Summary | Baseline | No Duplicate | 25% Duplicate Parts | 50% Duplicate Parts | 75% Duplicate Parts |
|---|---|---|---|---|---|
| **Percent Duplication** | 1 | 0 | 0.25 | 0.5 | 0.75 |
| **Life Cycle Costs ($M)** | 161.8 | 197.7 | 188.8 | 179.8 | 170.8 |

### c. Currency Rate

For the calculation of the cost of not duplicating the maintenance assets over time, the largest component is the costs to hire a commercial freight trucker to move the IMRL and tool items, of which there is only one copy, back and forth to each operational location. Funds required to replace items that are broken, lost, or damaged during the transit also play a factor, but the magnitude of that expenditure is far less than the transportation costs themselves. As the geographical location of the two bases between which the material is transported is in a foreign country, the payment for transportation is made in a currency other than United States dollars. If the American government were to purchase a fleet of trucks that could be made available for periodic air-wing transportation as well as other base requirements, then the foreign currency variable would be eliminated. However, the cost of purchasing such a fleet of freight trucks is prohibitively high and is not economically viable even if used for other United States Forces -Japan requirements, other than strike force readiness.

The unit of currency in which the usage rates for the freight trucks will be paid is the Japanese yen. Financial trends over the past decade have seen a gradual strengthening of the yen in relation to the American dollar, resulting in higher expenses when expenditures are made in Japanese currency. As the level of inflation in Japan over the same time period has been virtually zero, any changes in labor costs can be attributed mainly to exchange rates.

The yen rate during the first few years of the millennium was in the neighborhood of 120 yen to the dollar, which gave the American forces the incentive to conduct more business with Japanese workers because of the favorable exchange rate; this factor is separate from the generally high cost of skilled labor in Japan. The last few years

of the decade have seen a dramatic decrease in the purchasing power of the dollar in Japan, and a more typical current exchange rate is at or below 80 yen to the dollar. Table 3 depicts changes in the total life-cycle ownership costs for a single set of assets when the conversion rate varies by 10 points. Such a fluctuation drives a difference in ownership costs of $449 million.

Table 3 demonstrates an important lesson that can be learned from this model is that the global financial landscape is constantly shifting and assumptions made with out-of-date data are apt to be inaccurate. When establishing a life-cycle cost for an investment undertaken in a foreign currency, contingencies should be made for the cost assumption to vary over time, or the final outcome will be artificially high or low, depending on which direction the exchange rate varies from the known amount at program inception.

**Table 3. Scenario Summary Due to Change in Currency Rate**

| Scenario Summary | Current Values: | 83 Yen to $1 | 91 Yen to $1 | 111 Yen to $1 | 125 Yen to $1 |
|---|---|---|---|---|---|
| **Exchange Rate** | 1 | 1.2 | 1.1 | 0.9 | 0.8 |
| **Life Cycle Cost ($M)** | 197.74 | 198.63 | 198.19 | 197.29 | 196.84 |

### *d. Discount Rate*

In a real government project, the figure would be pulled from the most recent version of the Office of Management and Budget (OMB) Circular Number A-94 (Office of Management and Budget, 2012). The discount rate applied is an important factor in determining the total life-cycle costs associated with the decision to purchase additional tool sets. Discount rates reflect the degree to which both costs and benefits in the future are less valuable than costs or benefits today. The selection of the proper discount rate can help the decision-maker choose the most efficient means of obtaining desired capabilities. The initial discount rate provided in the baseline scenario is 2%, which is the rate currently mandated by the OMB. A small increase or decrease in this

discount rate produces significant changes in the life-cycle cost, as demonstrated in Table 4. We have computed these changes using the scenario builder in Excel and provided the summary below.

**Table 4. Scenario Summary Due to the Discount Rate**

| Scenario Summary | | | | | |
|---|---|---|---|---|---|
| Discount Rate | 2% | 1% | 5% | 7% | 10% |
| Life Cycle Cost ($M) | 197.74 | 209.14 | 171.55 | 158.98 | 144.97 |

#### *e. Shared Maintenance Assets*

All other scenarios covered in this document assume that each Hornet squadron in the air wing, although operating similar T/M/S aircraft, do not share maintenance support assets as part of its routine operations. There is great redundancy in the material outfitting of each squadron because the tool container procedures manual for Naval aircraft do not take into consideration that several squadrons operating the same type of airframe will be operating in close proximity in an operational environment such as a ship. In fact, the redundancy goes beyond the air-wing level and exists even within the squadrons themselves. Because individual squadrons can operate in a detachment basis, they are required to maintain a certain level of tools and IMRL, depending on how many aircraft are attached to the command. This excess inventory would be critical to cover all unlikely events if each maintenance department operated in total isolation, but when applied to the real world environment in which a forward-deployed carrier exists, it results in excessive inventory costs for unnecessary capacity.

To determine whether there would in fact be a cost savings as compared to the baseline by reducing the amount of maintenance assets purchased, we calculated the total life-cycle costs under the current paradigm where each squadron is equipped with all the mandatory and optional tool and IMRL items for the number of aircraft supported, as well as for a scenario in which each full set of maintenance materials is used to support two squadrons rather than one. As might be expected, the total life-cycle costs for the scenario where the assets are shared evenly in the squadron is half of the costs for sole

possession. The attractive aspect of this concept is that it is the only version where total life-cycle costs are less than that of the baseline. Although beyond the scope of this project because it would involve changing multiple variables at the same time, further potential for savings exists by sharing assets between squadrons within the air wing while simultaneously duplicating a portion of the assets to save on transportation funding. The scenario summary of a shared maintenance assets situation is presented in Table 5.

**Table 5. Scenario Summary Due to Shared Maintenance Assets**

| Scenario Summary | Current Values: | 2 Sets of Tools/IMRL |
|---|---|---|
| **Full Sets of Tools/ IMRL** | 4 | 2 |
| **Lifecycle Cost ($M)** | 197.7 | 98.9 |

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# V. CONCUSIONS AND RECOMMENDATIONS

This chapter serves to distill the information that we derived from the data on air-wing maintenance material equipage support that we gathered during the literature review and analyzed in the quantitative portions of the document into a coherent recommendation on how to proceed with future material procurement doctrine. In expressing the recommendation, we apply weight to specific assumptions; the overall conclusion that we derive varies accordingly. We also identify and address special considerations pertaining to the current state of naval aviation.

## A. RECOMMENDATION

Two of the most robust outcomes from the sensitivity analysis we performed on the five factors affecting the total life-cycle costs of maintenance support assets were that a full duplication of assets was less costly over 20 years than any form of partial duplication that required transportation, and also that a modification of existing tool and IMRL usage regulations to allow squadrons to jointly share maintenance assets has the potential to halve the ownership costs over a given time period. The framework that we developed to investigate the impact of the fluctuation of a discrete variable does not lend itself to tracking the complex interrelationships formed by the simultaneous modification of multiple variables, but intuitively the combination of these two phenomena has the potential to drive even greater cost savings than the implementation of either in isolation. In practice, the implementation of one of these concepts could be used to fund the other, so through their application there would be no net increase to the total life-cycle costs of the maintenance support package overall; transportation costs would be eliminated while still providing a full complement of assets for maintenance requirements at each operational location.

The concept behind this assertion is that a full set of maintenance assets should be available at each location to eliminate transportation costs, to have back-up assets located in the same theatre, and to discontinue the loss of maintenance man-hours in packing and unpacking the entire support package upon each deployment evolution. The downside to

such a scenario is that for the plan to be implemented there is an up-front cost of $20.2 million for each Hornet squadron, or $80.9 million for the entire air wing. These initial purchasing costs, however, are avoided by using assets that have already been procured to support the transition. Under the current paradigm, each one of the four Hornet squadrons in the air wing possesses an over equipage of tools and IMRL items so that it can operate alone in any environment. That requirement is not realistic insofar as carrier-based aircraft squadrons are in close proximity to other similar activities, precluding the need for this redundancy. If the four squadrons were to break down into two pairs of sister activities that shared half of a maintenance material equipage, then the other full half of the equipage would be surplus and could be pre-positioned at the squadron's alternate operational site. In this method, full utilization is made of available assets at minimal costs. Leeway does exist in this concept in that if there were not a 50/50 split of the assets where the CAG leadership felt that slightly more than half of the assets were necessary to support an operational location, then the difference of assets could either be transported back and forth between deployment sites or a plus-up could be performed for those specific assets if it were more cost effective to do so.

## B. CONSIDERATIONS IMPACTING THE RECOMMENDATION

### 1. Paradigm Shift

#### *a. Shift to Pooling Common Resources from Current Navy Culture*

There have always been inter-Service rivalries, such as the Army-Navy football game every year that creates a friendly yet competitive environment. Rivalry exists not only in sports but also in many other facets of naval tradition and history. Officers are ranked against their peers, and these ranking have a great impact on whether that officer is selected for his or her next and higher pay grade and whether he or she successfully screens for command of a ship, squadron, submarine or base. This type of rivalry and competitiveness carries itself over within the naval aviation community, where each individual squadron tries to outperform the other similar T/M/S squadrons on their respective coasts for awards. This coastal competition comes from the fact that each year,

one squadron on each coast is selected as the best in its class by receiving the coveted Battle Efficiency award. The Battle Efficiency Ribbon was established in July 1976 by Secretary of the Navy J. William Middendorf (Navas, 2008).

> The aviation Battle “E” is the Navy’s top performance award presented to the aircraft carrier and aviation squadron in each competitive category that achieves the highest standards of performance readiness and efficiency. The award recognizes a unit's training and operational achievements while including a balance that incentivizes efficiency. (Commander, Naval Air Forces Public Affairs, 2011)

One of the main performance criteria that a squadron must perform well to be considered for the award is how well it performs on its aviation maintenance inspection (AMI), performed by the Commander, Naval Air Forces Aviation Maintenance Management Team (AMMT) every 18–24 months, depending on the squadron’s deployment cycle. There are 41 NAMP programs and processes that are evaluated during these inspections that last from three to five days. In 2010, the most recent year for which data is available, the TCP at the organizational level was ranked as the 10th NAMP program most often graded as off track or in need of more attention by CNAF AMMTs (Rosas, 2012). Additionally in 2010, the Support Equipment Planned Maintenance System (SEPMS) program, of which IMRL plays a significant role, was ranked as the fifth NAMP program most often graded as off-track or in need of more attention by CNAF AMMTs (Rosas, 2012). Failing any of these two programs leads to a decrease in the squadron’s final grade on the inspection which, if included with other off-track or needs-more-attention programs, can take a squadron out of contention for the Battle Efficiency award. Because competition is fierce, each squadron goes to great lengths to ensure that its 41 NAMP programs and processes are in the best shape possible. Commands who receive the Battle Efficiency award are held to the pinnacle of esteem in their respective aviation communities, which tremendously impacts the periodic fitness reports for commanding officers and maintenance officers. The way in which the metric leading to the selection of the recipient of the Battle Efficiency award is calculated severely discourages similar squadrons to share their assets because they are in direct competition with one another. There must be a paradigm shift for squadron’s to share limited NAE resources.

### *b. Navy and Marine Corps Joint Management of Support Assets when Collocated*

With the relocation of the CVW-5 fixed-wing aircraft from NAF Atsugi to MCAS Iwakuni, there are redundancy possibilities that come into play. Although MCAS Iwakuni is a Marine base, the Marine hornet squadrons have Hornet aircraft assigned. Presently, they have the F/A-18 C/D legacy Hornets, but these assets are still Hornets, and their tool and IMRL support composition is very similar. In fact, the Marine Corps TCP is the exact same as the one administered by their Navy counterparts because the aircraft specific tool control manuals that guide maintenance and the overall NAMP direction is shared by the two components. The tool control manual does not differentiate among Hornet versions; there is only one manual that is titled *Aircraft Tool Control Manual, Navy and Marine Corps Model FA-18* (Commander, Naval Air Systems Command, 2007). Sharing duplicate resources could provide a win-win scenario for both the Navy and the Marine Corps if inter-Service rivalries can be overcome.

### *c. Compliance*

Several recommendations proposed in this literature run counter the standard operating procedures of the NAMP and would therefore require approval from higher authority prior to implementation. An example of such a procedure would be tailoring the allocation of assets to a squadron as a different quantity than the one based on the number of assigned aircraft per the applicable T/M/S TCP manual. Such a procedure would require buy-in from all the pertinent stakeholders and approval by CNAF Code N422. Detailed procedures for requesting an NAMP deviation are provided in Section 1.1.4.3.2 of the first chapter of the NAMP, where an overview of the instruction as well as a description of aviation maintenance organizational levels is offered (CNAF, 2009).

However, prior to any submission of a formal deviation request, the individuals submitting the request should be working in close coordination with the leadership of the AMMT, who represent CNAF Code N422C1 (CNAF, 2009). The AMMT teams are charged with the evaluation of performance in aircraft maintenance activities and the identification of areas that require modifications in behavior to maintain efficiency, to promote safety, and to facilitate compliance with the NAMP and any

situation-specific instructions (CNAF, 2009). As such, the AMMT teams are all composed of subject-matter experts in the myriad disciplines covered by the umbrella of aviation maintenance and are uniquely qualified to give advice into what departures from standard operating procedures constitute a situational deviation or a broad-scale change that applies to all activities performing maintenance on aircraft or aircraft components. Another benefit of involving the AMMT leadership early in the planning process of any prospective changes or deviations to the NAMP or other instructions is that the AMMT team is also the entity that performs the periodic AMIs and maintenance program assist (MPA) visits to operational commands (CNAF, 2009). By soliciting their recommendations early into the regulation modification process, confusion can be avoided as to what standards the activity will be evaluated on during its cyclic performance and compliance evaluations.

#### *d. Evolution of the Nuclear Aircraft Carrier Deck-Load Configuration*

The footprint of the carrier air wing has changed dramatically in the past 21 years. In 1991, when Operation Desert Storm was underway, a typical aircraft carrier's fixed-wing assets consisted of the following types of squadrons: F/A-18 Hornet; A-6E Intruder; F-14 Tomcat; S-3 Viking; and E-2C Hawkeye. This air-wing configuration is what was used for CVW-1, which was deployed aboard the USS *America* (CV 66; Strike Fighter Squadron Eighty-Two, 2006). During Desert Storm, there was typically one Hornet squadron that performed both strike fighter and attack capabilities, two F-14 Tomcat squadrons that provided fighter and close air support, one S-3 Viking squadron used to identify and track enemy submarines, and one A-6E squadron used for attack. Each of these squadrons had a complete set of tools and IMRL that it transported to and from the ship every deployment. At the time, the self-sufficiency concept made sense because other than the aging F-14 Tomcat squadrons, each squadron was the only one of its type aboard the carrier with the closest similar squadron possibly 12,450 miles away. In 2015/6, the new and improved air-wing footprint of CVW-5 will consist of three F/A-18E squadrons, one F/A-18F squadron, and one F/A-18G squadron that will be employed to accomplish the same missions as the previous air-wing configuration. The main

difference the constituency update presents is that there are now redundancies and multiple duplications of similar assets among these Hornets squadrons. Other than the type mission that the Hornets are assigned, they are basically still Hornets utilizing the same type tools and IMRL as each other and within close proximity of each other, never to exceed the length of the flight deck, or 1,092 feet (Schultz, 2012). There are some differences in tools and IMRL outfitting between the different configurations of aircraft, but the majority of the support items are the same. Based on these factors, we argue for a pooling of resources to prevent excess expenditures related to non-mission enhancing redundancies.

### 2. Discount-Rate Selection

We selected the 2% discount rate as the default in our analysis because it is the rate directed by the Office of Management and Budget (OMB) in the 2012 augment to Circular Number A-94 (Office of Management and Budget, 2012). Although the usage of this essentially risk-free rate may be in line with standard procedures for calculating the net present value of a long-term government investment, it would be wise for a logistician who is making the decision on how to allocate resources for aviation maintenance support to consider other numbers for the discount rate simply because this variable has more impact on the eventual life-cycle cost calculation than any other term. Small raises in the selected discount rate will result in much lower total life-cycle ownership costs, while a decrease in the discount rate by even a small amount will drastically increase the life-cycle ownership costs of the enterprise (see Table 4).

Whether to use the discount rate that the OMB circular advocates or to depart from that recommendation depends on how damage is weighted in the analysis. If there is to be no further risk analysis in the assessment, then the risk of the scenario should be factored into the discount rate to take into account the unknowns the future will hold, such as fluctuating foreign currency rates or extreme variation in the projected deployment OPTEMPO. Conversely, if further risk analysis is performed with a data product calculated using the discount rate as a variable to determine total projected life-cycle costs, then the risk-free rate listed in the OMB circular is appropriate because it would prevent the double counting of risk in the final estimation. We provide this recommendation for

the benefit of future researchers so that the uncertainty of life-cycle costs is not over- or under-weighed when making procurement decisions.

### 3. Research Continuation

The objective of this analysis was to make recommendations as to how IMRL and tools were to be procured for the FDNF air wing's maintenance support package. We proposed a scenario in which all of the IMRL and tool assets would be duplicated, and we then sought to determine whether such a full duplication was warranted, or whether the government would be better served with a partial duplication or no duplication at all, which is the current paradigm. The results from modeling different scenarios showed that in certain circumstances, full duplication is favorable; although when conditions were slightly modified, a partial duplication then yielded a lower total life-cycle cost. Under no scenario did abstaining from any duplication and pursuing a plan of strict transportation of one set of assets yields the lowest ownership costs when taken over a 20-year period. The partial and full duplication plans do not need any further explanation because their very names detail exactly how they will be prosecuted, but at this juncture a recommendation on how the partial duplication plan could be prosecuted is warranted.

Although beyond the scope of this document, the sources that we utilized in our analysis have provided relevant information on maintenance support asset costs to include the weight and cube size of all items used to maintain a Hornet squadron, both IMRL and tools. We recommend that if maintenance leadership were to pursue the option of partially duplicating the material support package for the FDNF air wing that they solicit a further study into which items should be duplicated and which items should be transported based on the cost data used in this document, as well as the dimensional data that was obtained as a byproduct. A unique opportunity for this follow-on project is represented in the current Naval Postgraduate School student body as two aerospace maintenance duty officers with extensive organizational level maintenance experience. Additionally, the completion of an FDNF maintenance material control officer tour is in the Business School pipeline for 827 logistics MBA completion. This project, as well as its supporting data, will be forwarded to these students for research continuity.

## C. TOTAL LIFE-CYCLE OWNERSHIP COSTS

The total life-cycle ownership costs upon initial outfitting for the maintenance support assets of four Hornet squadrons with a full duplication of resources and therefore no transport costs is $80.9 million. When resource sharing between sister squadrons is factored into the scenario, then the total life-cycle ownership costs with full duplication and no transport for four squadrons split into two groups of two is $40.4 million, resulting in a cost savings of the same magnitude as the expenditure. This savings is taking into consideration that a full set of assets will be purchased for the establishment of a new air wing, which is not the case for our project because a full four-squadron outfitting is already possessed. For an established air wing, the savings over 20 years would actually be the net present value of potential transportation costs because two full sets of maintenance assets would already be located at the primary operational locations. We calculated the projected 20-year cost savings figure returned by our quantitative model to be $110 million. This number represents only the possible cost savings for CVW-5, but the central concept of pooling resources would also be able to be applied to future sharing of resources among other carrier deploying Hornet squadrons in NAS Lemoore. The same model could not be applied to NAS Oceana home ported Hornet squadrons because their homeport is much more closely positioned to their deployable platform. If all the tenants of our model were to hold true across the entire NAE, then the potential savings could be ($110 million * 5 CVWs) for a sum of $550.5 million over 20 years for the five air wings home ported in MCAS Iwakuni and NAS Lemoore. However, this model could not be directly applied to the four NAS Lemoore air wings because this simulation was tied to the time value of the transportation costs for Japan. In that circumstance, the pertinent domestic transportation cost data could be applied to transportation costs in the continental United States where the transportation of tools/IMRL would exceed 300 miles from Hornet base to CVN home port in San Diego and Washington State.

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